

TOOLS AND THEIR USE RELATED TRAINING FOR HEP ELECTRICAL AND MECHANICAL APPRENTICE

Released by • DEPARTMENT OF WATER RESOURCES
Division of Operations & Maintenance • Technical Development Section

TOOLS AND THEIR USES

Introduction

Tools and their uses are very important to a mechanic. Therefore, the subject of tools is the logical starting point of any maintenance training program.

The use of handtools and of portable power tools is basic to any maintenance job classification. For the person who desires to become a skilled mechanic it is essential for him to develop his abilities to properly select, use, handle, and care for the hand and power tools made available for him to use in the performance of his work.

This chapter is designed to present, in a concise form, the basic operations required for the performance of a wide variety of jobs. Few jobs consist of a single operation, but when the separate operations are properly learned, it becomes a fairly simple matter to combine separate operations so as to meet the requirements of specific jobs. For example, the overhaul and repair of a damaged pump requires the knowledge of several operations; measuring, threading, layout, cutting to size, and use of a variety of tools. The mechanic trainee who has learned to do the individual operations should have no trouble with the various combinations of operations necessary to perform the overall job.

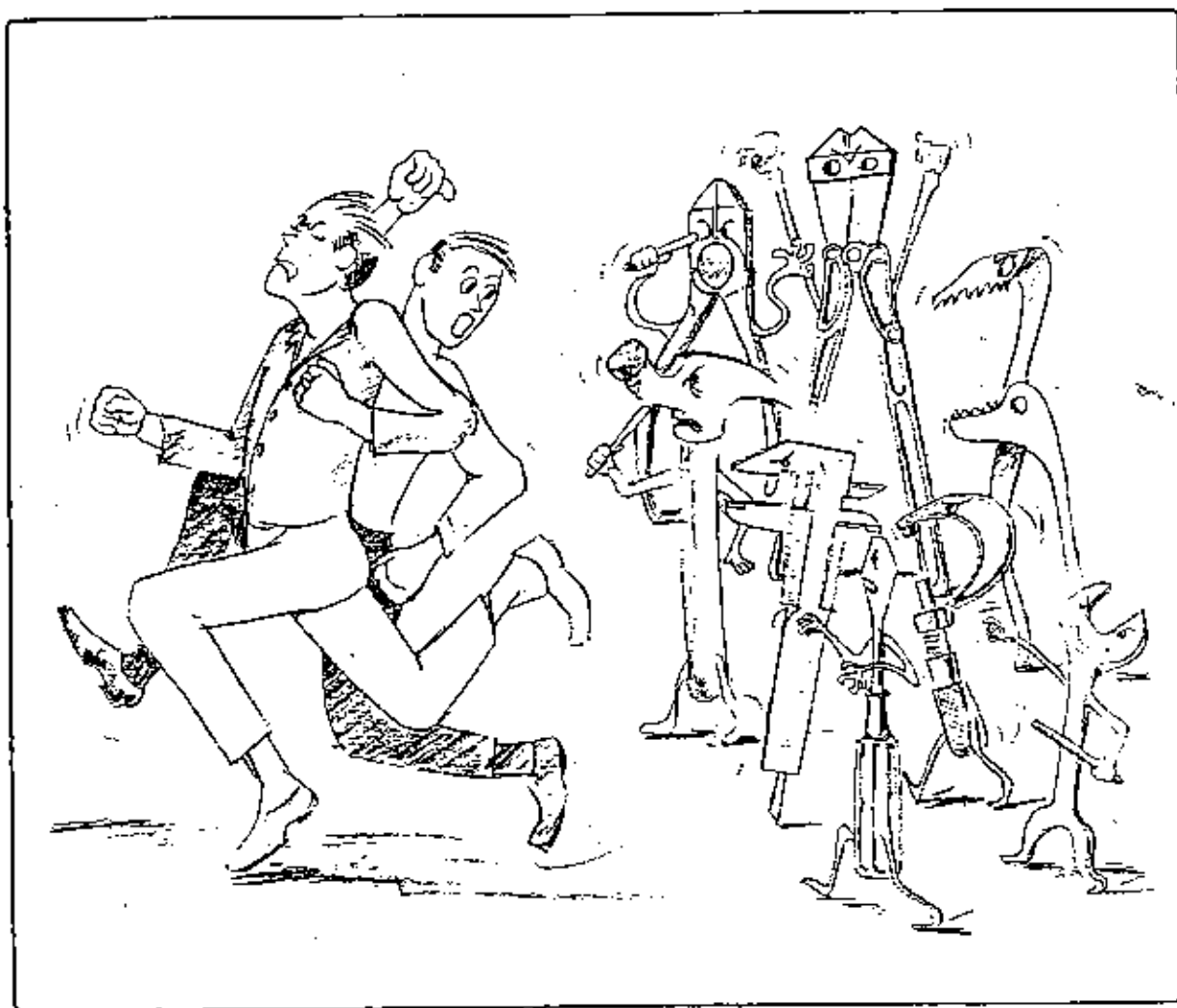
The individual operations described in this chapter cover the following broad areas; measuring skills; layout skills such as testing, checking, and setting; woodcutting skills; grinding and filing; and metal cutting skills. A description of how this chapter may be used to the best advantage by the maintenance trainee is shown below:

1. When you are assigned a job that involves the use of any of the handtools covered, study the text material relating to the operation and study the illustrations.
2. Study the description, illustration, general uses, and maintenance procedures for the tool or tools involved in the job.
3. If possible, practice each operation for a few times, before starting the job. Have an experienced mechanic check your performance after you have practiced each operation.
4. As you perform in each skill area, keep track of your newly developed proficiencies until you have successfully covered all of the normal operations involving the use of handtools and portable power tools.

5. Some of the hand or power tools described in this chapter may neither be available nor needed in certain job classifications. Some of the operations and skills relating to the use of a particular tool may either be not permitted or not accepted as standard practice in certain areas because of a conflict in craft responsibilities. Always check with your supervisor in these doubtful cases.

6. The last step is careful practice, until you have mastered the various skills involved. The end result must be that you become capable of performing the required operations, and of meeting the standards established by your supervisors.

Remember--tools are a mechanic's best friend if treated as such, but if mistreated or misused through ignorance or carelessness, they will not only be short-lived, but can prove to be dangerous adversaries.



MISTREAT US ... WILL YOU?

COMMON HANDTOOLS

There are certain tools that are common to many jobs. Regardless of what your classification is, you should become familiar with the common tools and their uses. Sometime during your career you probably will be called upon to do a job where one or more of the tools discussed here will have to be used.

HAMMERS

A toolkit would not be complete without at least one hammer, and in most cases two or three hammers are included. Hammers are designated according to weight without the handle, and style or shape.

The shape will vary according to the work for which they are intended. For the purpose of this discussion hammers will be broken into three classes; machinist's hammers, carpenter's hammers, and mallets and sledges.

MACHINIST'S HAMMERS

Machinist's hammers are used primarily by people who work with metal or around machinery. Machinist's hammers may be further divided into two classifications—HARD-FACE and SOFT-FACE.

The hard-face hammer is made of forged tool steel. The best general purpose machinist's hammer is the ball-peen hammer. (See fig. 1-1-1.) The flat end of the head is called the face. This end is used for most of the hammering jobs you will have. The other end of the hammer is called the peen. The peen end is smaller in diameter than the face and is therefore useful for striking areas that are too small for the face to enter. The peen is also useful for braddding rivets.

Ball-peen hammers are made in different weights, usually 4, 6, 8, and 12 ounces and 1, 1 1/2, and 2 pounds. For most work a 1 1/2-

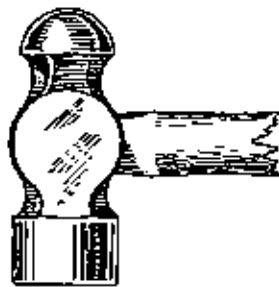


Figure 1-1-1.—Ball-peen hammer.

pound and a 12-ounce hammer will suffice. However, a 4- or 6-ounce hammer will often be used for light work and especially useful for cutting gaskets out of sheet gasket material.

There are variations of the peening hammer such as the cross-peen and the straight-peen as shown in fig. 1-1-2.

The soft-faced hammers, used by people who are working with metal or around machinery, are hammers that have a head made from brass, lead, or a tightly rolled strip of rawhide. Plastic-tipped hammers, or solid plastic with a lead core for added weight, are becoming increasingly popular.

Soft-faced hammers, (fig. 1-1-3) should be used when there is danger of damaging the surface of the work, as when pounding on a machined surface. Most soft-faced hammers have heads that can be replaced as the need arises. Lead-faced hammers, for instance, quickly become battered and must be replaced, but have the advantage of striking a solid, heavy nonrebounding blow that is useful for such jobs as driving shafts into or out of tight holes. If a soft-faced hammer is not available, the surface to be hammered may be protected by covering it with a piece of soft brass, copper, or hard wood.

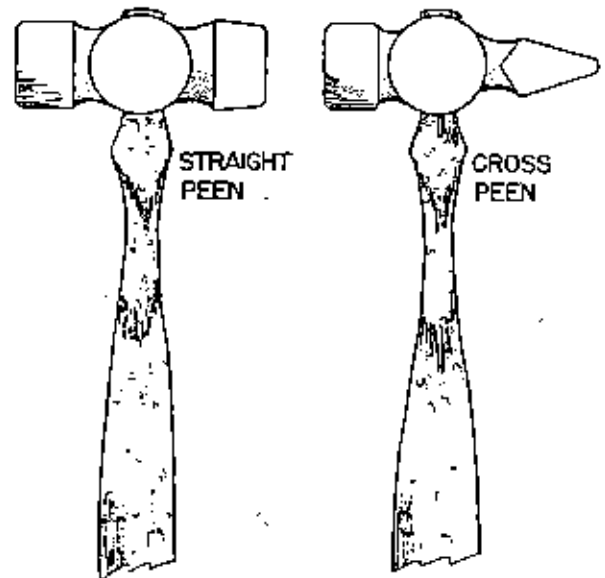


Figure 1-1-2.—Variations of the ball-peen hammer.

Simple as the hammer is, there is a right and wrong way of using it. (See fig. 1-1-4.) The most common fault is holding the handle too close to the head. This is known as choking the hammer, and reduces the force of the blow. It also makes it harder to hold the head in an upright position. Except for light blows, hold the handle close to the end to increase the lever arm and produce a more effective blow. Try to hit the object with the full face of the hammer.

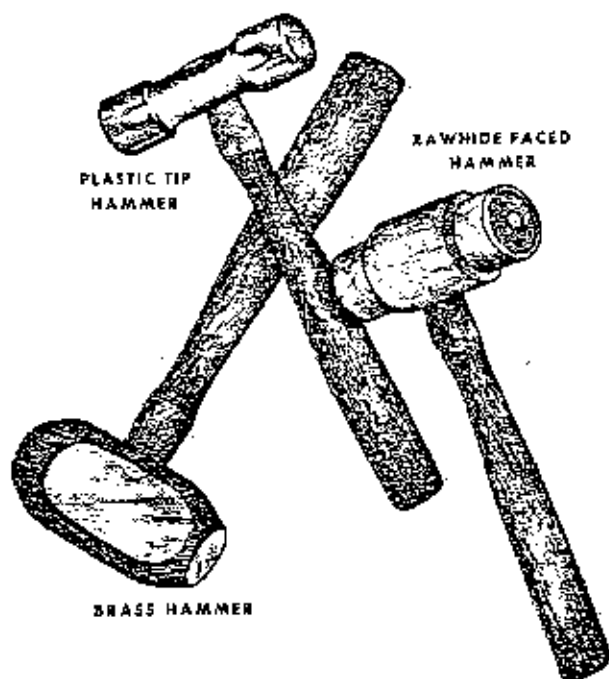


Figure 1-1-3.—Soft face hammers.

Hold the hammer at such an angle that the face of the hammer and the surface of the object being hit will be parallel. This distributes the force of the blow over the full face and prevents damage to both the surface being struck and the face of the hammer.

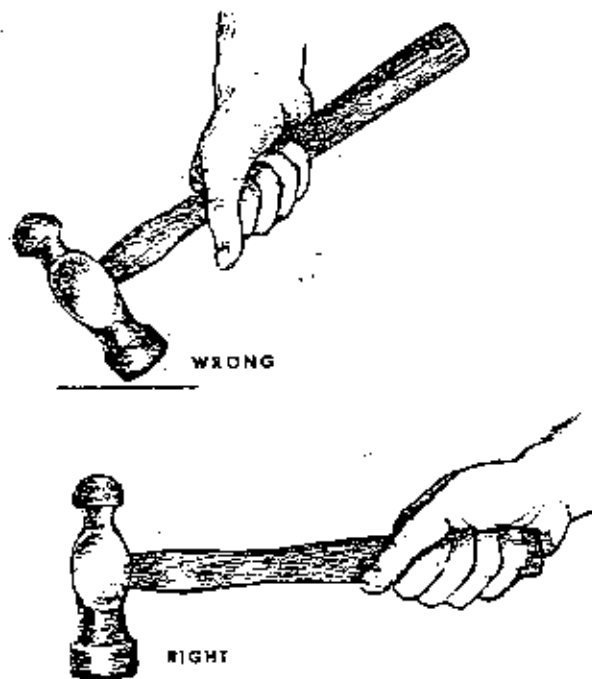


Figure 1-1-4.—Right and wrong way to use a ball-peen hammer.

CARPENTER'S HAMMER

The carpenter's hammer is either a curved-claw or straight-claw hammer. The face may be either a bell-faced or plain faced. (See fig. 1-1-5.) The carpenter's hammer generally used is the curved claw, bell-faced hammer. The hammers may have either a steel or wooden handle; however the steel handle is most common. The primary use of the carpenter's hammer is to drive or draw (pull) nails.

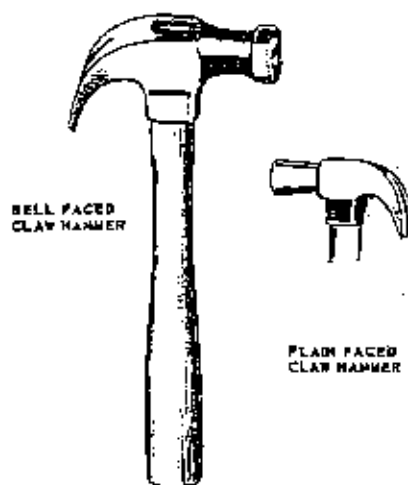


Figure 1-1-5.—Bell-faced and plain faced claw hammers.

MALLETS AND SLEDGES

The mallet is a short-handled tool used to drive wooden-handled chisels, gouges, wooden pins, or small stakes. It is also used to form or shape sheet metal where hard-faced hammers would mar or injure the finished work. For example a rubber-faced mallet is used for knocking out dents in an automobile. Its heads are made from a soft material, usually wood, rawhide, or rubber. It is cylindrically shaped with two flat driving faces that are reinforced with iron bands. (See fig. 1-1-6.) The mallet and hammer are used in the same way. Never use a mallet to drive nails, screws, or any object that may cause damage to the face.

The sledge is a steelheaded, heavy duty driving tool that can be used for a number of purposes. Short-handled sledges are used to drive bolts, driftpins, and large nails, and to strike cold chisels and small hand rock drills. Long-handled sledges are used to break rock and concrete, to drive spikes, bolts, or stakes, and to strike rock drills and chisels.

The head of a sledge is generally made of a high carbon steel and may weigh from 6 to 16 lb. The shape of the head will vary according to the job for which the sledge is designed.

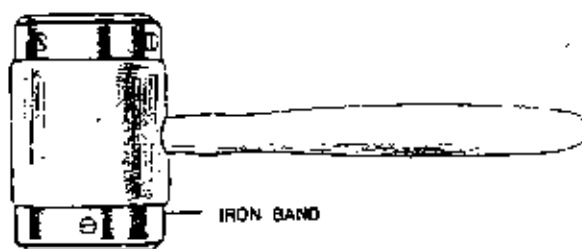


Figure 1-1-6.—Steel reinforced wooden mallet.

MAINTENANCE OF STRIKING TOOLS

Hammers, sledges, or mallets should be cleaned and repaired if necessary before they are stored. Hammer and sledge faces should be free from oil or other material that would cause the tool to glance off nails, spikes, or stakes. The hammer heads should be dressed to remove any battered edges. Inspect the handles of striking tools and make sure they are secure to the head and do not have any cracks or splinters.

Never leave a wooden or rawhide mallet in the sun, as it will dry out and may cause the head to crack. A light film of oil should be left on the mallet to maintain a little moisture in the head.

Replace Hammer Handle

When a hammer handle becomes damaged or loose in the hammerhead, it should be replaced before the hammer is used. A serious injury to yourself can result from using a hammer that has a bad handle.

The first step in replacing a hammer handle is to remove the old handle. If the handle is tight in the head, saw off the old handle next to the head. (See fig. 1-1-7.) Do not saw the handle off so close to the head that the saw teeth will touch the head while sawing, thus damaging the set of the saw. A hacksaw may also be used for this purpose.

Place the head of the hammer in a vise and drill a hole in the part of the handle that remains in the head. Remove the rest of the handle by driving it from the head.

The new handle should fit snugly in the hammerhead. Use a wood rasp to shape the handle to fit the head. Check the fit of the head on the handle occasionally, and make sure you do not remove too much material from the new handle. After the correct fit has been attained, seat the

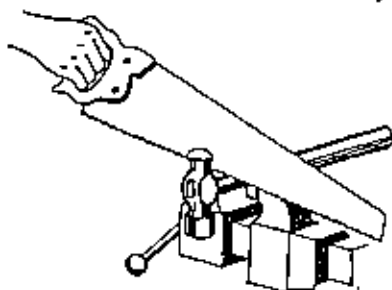


Figure 1-1-7.—Removing old hammer handle.

handle firmly in the head by hitting the end of the handle with a mallet. (See fig. 1-1-8.) Saw off the projecting portion of the handle, and use a small wood chisel to cut slits for the wedges if wooden wedges are used. Either wooden or metal wedges may be utilized. When the wedges have been driven in the handle, grind the end of the handle even with the head.

COMMON MISUSES

Never strike a hardened steel surface with a hammer. This misuse is a serious safety hazard. Small pieces of sharp, hardened steel may break from the hammer and also from the hardened steel. Besides causing damage to the work and/or the hammer, a serious eye injury may result.

Do not use a hammer handle for bumping parts in assembly, and never use as a pry bar. Such abuses will cause the handle to split, and a split handle can produce bad cuts or pinches. When a handle splits or cracks, do not try to repair it by binding with string or wire. REPLACE IT.

WRENCHES

A wrench is a basic tool that is used to exert a twisting force on bolt heads, nuts, and studs. The special wrenches designed to do certain jobs are in most cases variations of the basic wrenches that will be described in this section.

Some ratings will naturally have more use for wrenches in doing their jobs than other ratings; however, practically all

will have occasion, from time to time, to use wrenches. It is necessary, therefore, that all hands have a basic understanding of the description and uses of wrenches.

The best wrenches are made of CHROME-VANADIUM STEEL. Wrenches made of this material are light in weight and almost unbreakable. This is an expensive material, however, so the most common wrenches

are made of forged carbon steel or molybdenum steel. These latter materials make good wrenches, but they are generally built a little heavier and bulkier in order to achieve the same degree of strength.

The size of any wrench used on bolt-heads or nuts is determined by the size of the opening between the jaws of the wrench. The opening of a wrench is manufactured slightly larger than the bolt head or nut that it is designed to fit. Hex-nuts (six-sided) and heads are measured across opposite flats. A wrench that is designed to fit a 3/8-inch nut or bolt usually has a clearance of from 5 to 8 thousandths of an inch. This clearance allows the wrench to slide on and off the nut or bolt with a minimum of "play." If the wrench is too large, the points of the nut or bolt head will be rounded and destroyed.

OPEN-END WRENCHES

Solid, nonadjustable wrenches with openings in one or both ends are called open-end wrenches. (See fig. 1-1-9.) Usually they come in sets of

from 6 to 10 wrenches ranging from 5/16 to 1 inch. Wrenches with small openings are usually shorter than wrenches with large openings. This proportions the lever advantage of the wrench to the bolt or stud and helps prevent wrench breakage or damage to the bolt or stud.

Open-end wrenches may have their jaws parallel to the handle or at angles anywhere up to 90 degrees. The average is about 15 degrees. Handles are usually straight, but may be curved. Those with curved handles are called S-wrenches. Other open-end wrenches may have offset handles, to reach nut or bolt heads that are sunk below the surface.

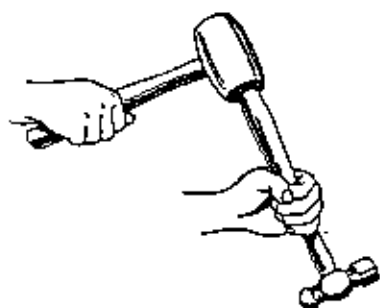


Figure 1-1-8.—Seating hammer handle in head.

One of the wrenches shown in figure 1-1-9 has jaws that are set on a 15-degree angle to the handle and one that is on a 90-degree angle. The reason why the jaws are placed at an angle becomes obvious when you have to work in close places.

There are special open-end wrenches, called TAPPET WRENCHES, which are very thin and have extra long handles. They are used to adjust the tappets of engine valves. These tappet wrenches are of light construction and the jaws of the wrench will spread easily, therefore, they should never be used for any purpose other than that for which they are intended.

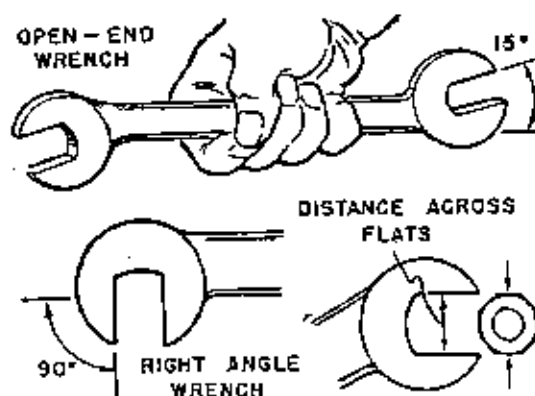


Figure 1-1-9.—Open-end wrenches.

BOX-END WRENCHES

Box-end wrenches have either 6, 8, 12, or

16 points inside the head. (See fig. 1-1-10.) The number of points determine the strength of the head. Six and eight point wrenches are used for heavy duty, 12 for medium duty and 16 for light duty work. The 12 point box-end wrench is the most common and can be used with a minimum swing of 30 degrees.

There is little chance of the box-end wrench slipping off the nut when the proper size wrench is used. Because the sides of the "box" opening are so thin, this wrench is suitable for turning nuts which are hard to get at with an open-end wrench. The offset box-end wrench (fig. 1-1-11) is especially useful in this respect.

There is one disadvantage to using box-end wrenches. You lose time if you use it to turn the nut all the way off the bolt once it is broken loose. You must lift the wrench completely off the nut after each pull, then place it back on in



Figure 1-1-10.—12-point box-end wrench.

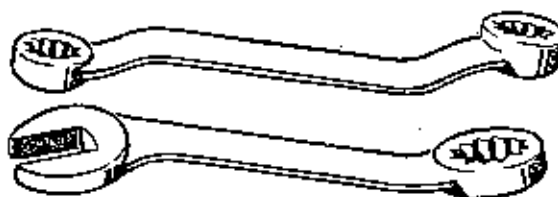


Figure 1-1-11.—Box-end and combination wrenches.

another position. The only time this procedure is not necessary is when there is room to spin the wrench in a complete circle.

After a tight nut is broken loose, it can be unscrewed much more quickly with an open-end wrench than with a box wrench. This is where a combination box-open end wrench comes in handy. (See fig. 1-1-11.) You can use the box-end for breaking nuts loose or for snugging them down, and the open end for faster turning.

For heavy-duty work, there are long-handled, single box-end wrenches. They are made only in the larger sizes, and you can apply all the pressure you need.

The correct use of open-end and box-end wrenches can be summed up in a few simple rules, most important of which is to be sure that the wrench properly fits the nut or bolt head.

When you have to pull hard on the wrench, as in loosening a tight nut, make sure the wrench is seated squarely on the flats of the nut.

PULL on the wrench—DO NOT PUSH. Pushing a wrench is a good way to skin your knuckles if the wrench slips or the nut breaks loose unexpectedly. If it is impossible to pull the wrench, and you must push, do it with the palm of your hand and hold your palm open.

Only actual practice will tell you if you are using the right amount of force on the wrench. The best way to tighten a nut is to turn it until the wrench has a firm, solid feel. This will turn the nut to proper tightness without stripping the threads or twisting off the bolt. This feel is developed by experience alone. Practice until you have mastered the feel.

Hammering on wrenches is strictly taboo—with one exception. There is a special type of box wrench, made strong and heavy so that you can hammer on it. The handle is short and has a steel pad on which the hammer blows are struck. This wrench is known as a slugging or striking wrench. Never place a piece of pipe over the handle of a wrench to increase leverage. This practice will damage the wrench and/or the nut or bolt that you are trying to tighten or loosen.

SOCKET WRENCHES

Early models of sockets were square or hexagonal sockets integral with a T or offset handle. (See fig. 1-1-12.) This type wrench is still in use but is generally made in large sizes. Socket sets presently used contain an assortment of individual sockets made to fit different handles. There are several types of handles and extensions (fig. 1-1-13), such as the T-handle, ratchet handle, screwdriver grip handle, and a speed handle. These handles and sockets can be assembled in combinations that will do most any job quickly and easily.

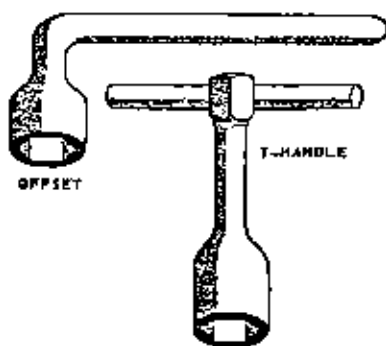


Figure 1-1-12.--Socket wrenches.

The nut opening of the socket is usually 8 or 12 points similar to the box-end wrench. Six-point sockets are still used for extra heavy-duty sockets or for large sockets. The end of the socket opposite the nut opening (fig. 1-1-14) has a square hole into which the handle fits. The size of the socket set is designated by the size of the square on the drive end of the handle. A spring loaded ball on the handle snaps into a groove in the socket to prevent it from falling off.

Sockets are usually furnished in sets for a range of different size nuts. The standard sizes

are 3/8-, 7/16-, 1/2- and 3/4-inch drive. The larger sizes have sockets that are designed for heavier work and larger size nuts. For extra-heavy-duty jobs larger size sets are available.

Sockets with thin walls may be obtained for use in extremely close quarters, but their use is not recommended for general work.

A universal joint (fig. 1-1-15) frequently comes in handy when working on nuts in places where a straight wrench cannot be used. The universal is placed between the handle and the socket and enables you to work the wrench handle at an angle to the socket. This comes in very handy when working in close places.

Large socket wrench sets also contain a set of extra deep sockets, generally 3 to 5 inches long. These sockets are especially useful when removing or replacing spark plugs or when removing or replacing nuts that are a long way down on the bolt.

Torque Wrench

An accessory for the socket wrench is a handle for the sockets that measures the amount of pull you exert on the wrench. This is called a "torque wrench." (See fig. 1-1-16.) This wrench is not supplied with the regular socket set but may be purchased separately.

Most modern-day machinery is assembled with close tolerances, therefore it is important that the correct amount of pressure be put on the nuts and bolts that hold it together. Manufacturers' manuals generally specify the amount of torque that is to be applied to the nuts. A torque wrench enables you to tell when these specifications have been met.

The accuracy of torque-measuring depends a lot on how accurately the threads are cut, and the cleanliness of the threads. Make sure you inspect and lubricate threads in order to get the most accurate torque reading possible.

ADJUSTABLE WRENCHES

A handy all-round wrench that is generally included in every toolbox is the adjustable open-end wrench. (See fig. 1-1-17.) This wrench is not intended to take the place of the regular solid open-end wrench for steady, hard service. One jaw of the adjustable open-end wrench is fixed; the other jaw is moved along a slide by a screw adjustment. The angle between the jaw opening and the handle is 22 1/2 degrees. The wrenches are available in varying sizes ranging from 4 to 18 inches in length.

When using the adjustable end wrench be sure to pull on the side of the handle attached to the fixed jaw. Make sure the jaws of the wrench are adjusted to closely fit the nut. A loose fit on the nut will tend to round off the corners of the nut.

When rotating round work an adjustable pipe wrench (Stillson) may be used. (See fig. 1-1-18.) The movable jaw on a pipe wrench is pivoted to

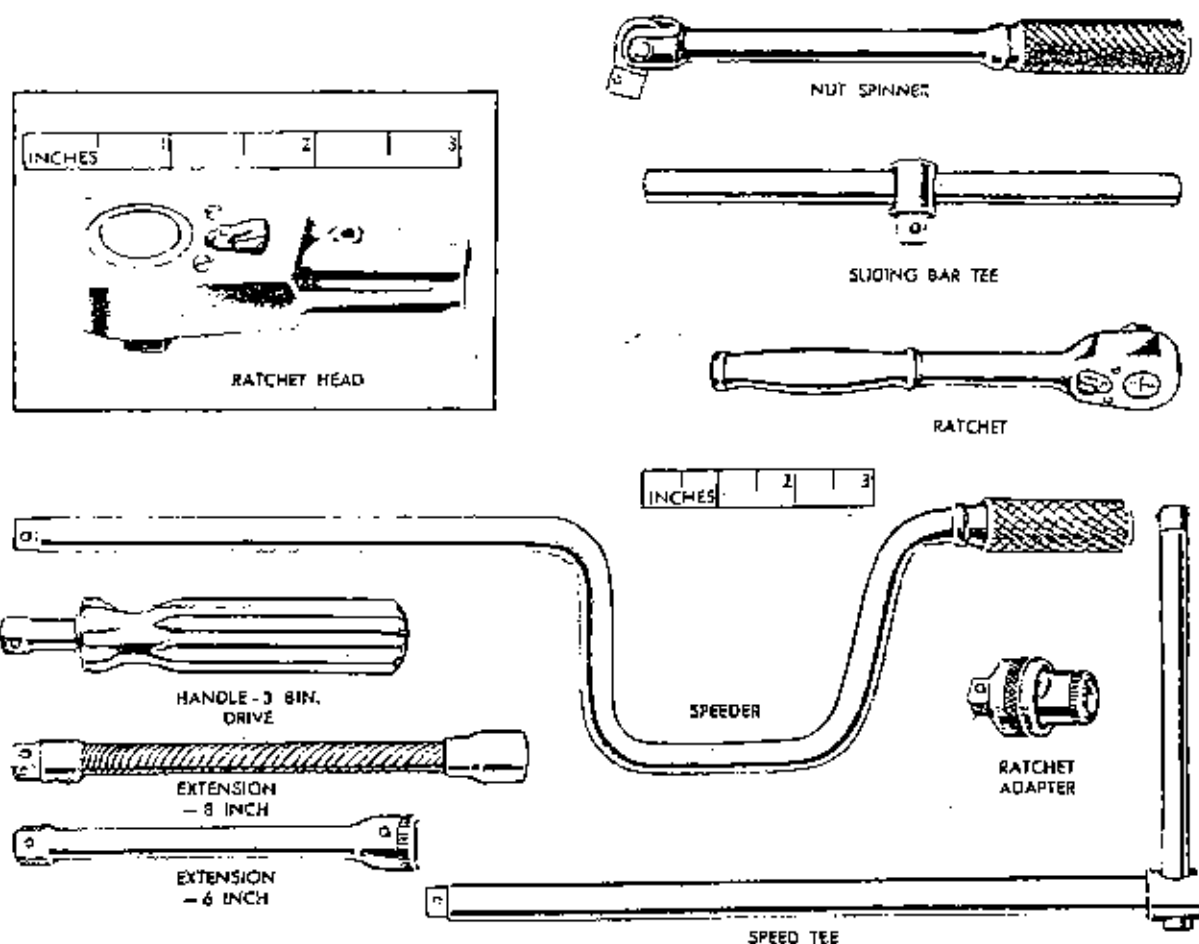


Figure 1-1-13.—Socket wrench ratchets, handles and extensions.

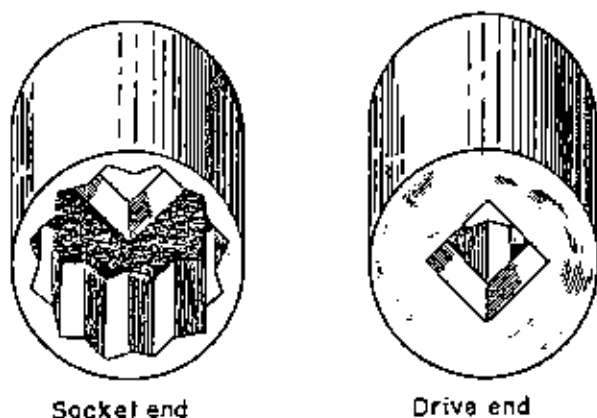


Figure 1-1-14.—12-point sockets.

permit a gripping action on the work. These tools must be used with discretion, as the jaws are serrated and always make marks on the work. The jaws should be adjusted so the bite on the work will be taken at about the center of the jaws.

A different type pipe wrench, used mostly on large sizes of pipe, is the chainpipe wrench. (See fig. 1-1-19.) This tool works in one direction only, but can be backed partly around the

work and a fresh hold taken without freeing the chain. To reverse the operation the grip is taken on the opposite side of the head. The head is double ended and can be reversed when the teeth on one end are worn out.

The strap type pipe wrench is sometimes used for turning pipe. It is similar to the chain pipe wrench but uses a heavy web strap in place of the chain. This wrench is used where you do not want to mar the surface of the work such as fittings and pipe that are chromium plated.

The old fashioned monkey wrench (fig. 1-1-20) is still used.

It works well on large square nuts, but is too bulky for most small jobs. The jaws make an angle of 90 degrees with the handle, and should always point in the direction of pull. In some models of the monkey wrench the jaws are adjusted by turning a knurled nut, in others the handle is turned.

SPANNER WRENCHES

Spanner wrenches are wrenches that are used on special nuts. They are not generally included in a toolkit but are kept in a central



Figure 1-1-15.—Universal joint for sockets.

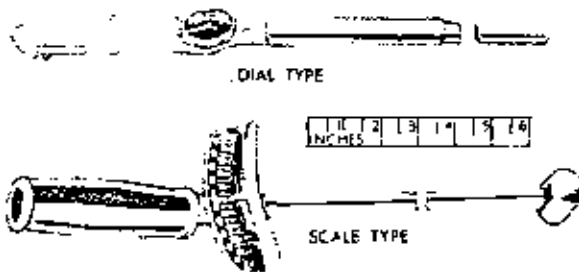


Figure 1-1-16.—Torque wrenches for use with sockets.



Figure 1-1-17.—Adjustable open-end wrench.

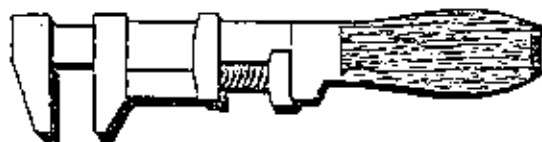


Figure 1-1-20.—Monkey wrench.



Figure 1-1-18.—Adjustable pipe wrench.

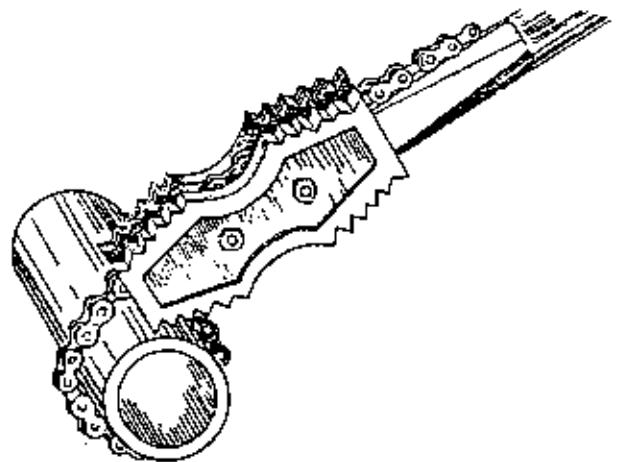


Figure 1-1-19.—Chain pipe wrench.

tool crib. They can be drawn out for use when the need arises. There are a number of types of spanner wrenches. The HOOK SPANNER (fig. 1-1-21) works on a round nut which has a series of notches cut in its outer surface. The hook (lug) is placed in one of these notches and the handle turned to loosen or tighten the nut. Fig 1-1-22 shows an adjustable type of spanner. The hook end of the wrench is hinged so that it will fit various sizes of nuts.

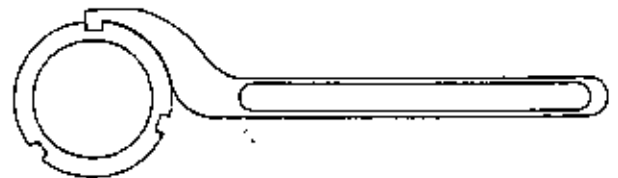


Figure 1-1-21.—Hook Spanner wrench.

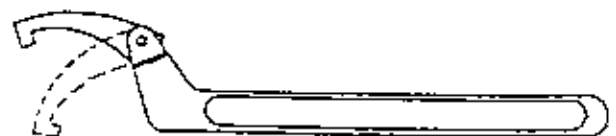


Figure 1-1-22.—Adjustable hook spanner wrench.

HEX-WRENCHES (ALLEN)

In some places it is desirable to use recessed heads on setscrews and capscrews. This type screw is used extensively on office machines and in machine shops.

Recessed head screws usually have a hex-shaped (six-sided) recess. To remove or tighten this type screw requires a special wrench that will fit in the recess. This wrench is called an Allen-type wrench. Allen-type wrenches are made from hexagonal L-shaped bars of tool steel. They range in size from 1/8 to 3/4 inch.

When using the Allen-type wrench make sure you use the correct size to prevent rounding or spreading the head of the screw.

NONSPARKING WRENCHES

Nonsparking wrenches are wrenches that will not cause sparks to be generated when working with steel nuts and bolts. They are generally made from a copper alloy (bronze). However, they may be made from other nonsparking materials.

Nonsparking wrenches must be used in areas where flammable materials are present. These tools are used extensively when working around gasoline-carrying vehicles and when working around aircraft.

RULES FOR WRENCHES

There are a few basic rules that you should keep in mind when using wrenches. They are:

1. Always use a wrench that fits the nut properly.
2. Keep wrenches clean and free from oil. Otherwise they may slip, resulting in possible serious injury to you or damage to the work.
3. Do not increase the leverage of a wrench by placing a pipe over the handle. Increased leverage may damage the wrench or the work.
4. Provide some sort of kit or case for all wrenches. Return them to it at the completion of each job. This saves time and trouble and facilitates selection of tools for the next job. Most important, it eliminates the possibility of leaving them where they can cause injury or damage to men or equipment.
5. Determine which way a nut should be turned before trying to loosen it. Most nuts are turned counterclockwise for removal. This may seem obvious, but even experienced men have been observed straining at the wrench in the tightening direction when they wanted to loosen it.
6. Learn to select your wrenches to fit the type of work you are doing. If you are not familiar with these wrenches, make arrangements to visit a shop that has most of them and get acquainted.

METAL CUTTING TOOLS

There are many types of metal cutting tools used by skilled mechanics of all ratings. As you become better acquainted with your rating, you will probably discover many tools that you use for cutting metal that are not described in this text. In this text, only the basic hand metal cutting tools will be considered. No matter how technical your work is you will find that certain jobs are done better and quicker with the basic handtool. The how to do certain jobs will be explained in a later section of this text.

SNIPS

One of the handiest tools for cutting light sheet metal is the hand snip (tin snips). The STRAIGHT HAND SNIPS shown in fig. 1-1-23 have blades that are straight and cutting edges that are sharpened to an 85-degree angle. Snips like this can be obtained in different sizes ranging from the small 6-inch snip to the large 14-inch. They are designed to cut sheet metal up to one-sixteenth inch in thickness. They will also work on slightly heavier gages of soft metals such as aluminum alloys.

Snips will not remove any metal when a cut is made. There is danger, though, of causing minute metal fractures along the edges of the metal during the shearing process. For this reason it is better not to cut exactly on the layout line in an attempt to avoid too much finish work.

Cutting extremely heavy gage metal always presents an opportunity to spring the blades. Once the blades are sprung, hand snips are useless. Use the rear portion of the blades only when cutting heavy material. This not only avoids the possibility of springing the blades but also gives you greater cutting leverage.



Figure 1-1-23.—Straight hand snips.

Never use tin snips to cut hardened steel wire or other similar objects. Such use will dent or nick the cutting edges of the blades.

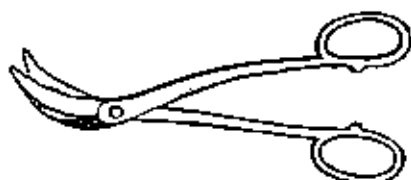
It is hard to cut circles or small arcs with straight snips. There are snips especially designed for circular cutting. They are called

CIRCLE SNIPS, HAWKS-BILL SNIPS, TROJAN SNIPS, and AVIATION SNIPS. (See fig. 1-1-24.) Use these snips in the same manner as you would use straight snips and observe the same precautions. Like straight snips they come in many different sizes.

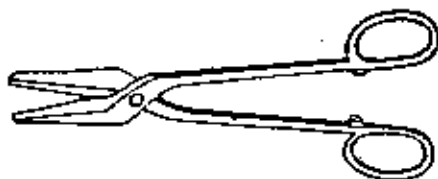
Many snips have small serrations (notches) on the cutting edges of the blades. This tends to



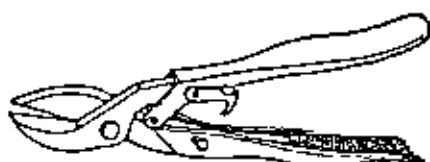
CIRCLE SNIPS



HAWKS-BILL SNIPS



TROJAN SNIPS



AVIATION SNIPS

Figure 1-1-24.—Snips for cutting circles and arcs.

prevent them from slipping backwards when a cut is being made. Although this feature does make the actual cutting much easier, it mars the edges of the metal slightly. You can remove these small cutting marks if you allow proper clearance for dressing the metal to size. There are many other types of hand snips used for special jobs. The snips discussed here can be used for almost any common type of work.

Learn to use snips properly. They should always be oiled and adjusted to permit ease of cutting and to produce a surface that is free from burrs. If the blades bind, or if they are too far apart, the snips should be adjusted.

Never use snips as screwdrivers, hammers, or pry bars. They break easily. Do not attempt to cut heavier materials than the snips are designed for. Never toss snips in a toolbox where the cutting edges can come into contact with other tools. This dulls the cutting edges and may even break the blades. When snips are not in use, hang them on hooks or lay them on an uncrowded shelf or bench.

HACKSAWS

Hacksaws are used to cut metal that is too heavy for snips. Such things as bolts and metal bar stock can be cut with hacksaws. There are two parts to a hacksaw; the frame and the blade. Common hacksaws have either an adjustable or solid frame. (See fig. 1-1-25.) Since hacksaw blades are made in different lengths, most hacksaws are of the adjustable frame type. Adjustable frames can be made to hold blades from 8 to 16 inches long, while those with solid frames take only the length blade for which they are made. This length is the dis-

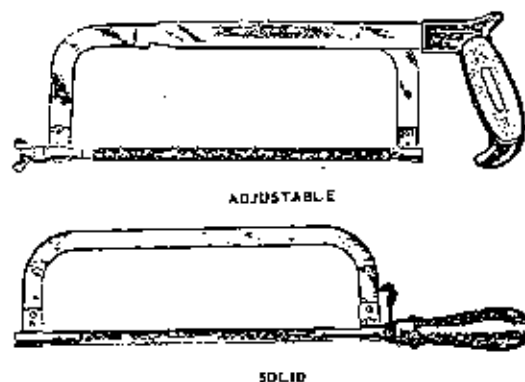


Figure 1-1-25.—Hacksaws.

tance between the two pins that hold the blade in place.

Hacksaw blades are made of high-grade tool steel, hardened and tempered. There are two types, the all-hard and the flexible. All-hard blades are hardened throughout, whereas only the teeth of the flexible blades are hardened. Hacksaw blades are about one-half inch wide, have from 14 to 32 teeth per inch, and are from 8 to 16 inches long. The blades have a hole at each end which hooks to a pin in the frame. All hacksaw frames which hold the blades either parallel or at right angles to the frame are provided with a wingnut or screw to permit tightening or removing the blade.

The SET in a saw refers to how much the teeth are pushed out in opposite directions from the sides of the blade. The four different kinds of set are ALTERNATE set, DOUBLE ALTERNATE set, RAKER set, and WAVE set. Three of these are shown in figure 1-1-26.

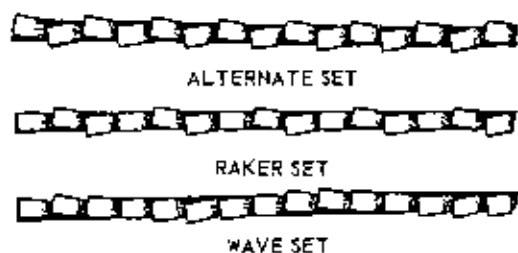


Figure 1-1-26.—"Set" of hacksaw blade teeth.

The teeth in the alternate set are staggered, one to the left and one to the right throughout the length of the blade. On the double alternate set blade, two adjoining teeth are staggered to the right, two to the left, and so on. On the raker set blade, every third tooth remains straight and the other two are set alternately. On the wave (undulated) set blade, short sections of teeth are bent in opposite directions.

The main danger in using hacksaws is injury to your hand if the blade breaks. The blade will break if too much pressure is applied, when the saw is twisted, or when the cutting speed is too fast. If the work is not tight in the vise, it will sometimes slip, twisting the blade enough to break it.

CHISELS

Chisels are tools that can be used for chipping or cutting metal. They are made from a good grade tool steel with a hardened cutting edge and a beveled head. They will cut any metal that is softer than materials of which they are made. When it is skillfully used, the chisel can be made to do most any job that a milling machine can do, although it is perhaps less accurate and requires greater time and energy.

Usually the bar stock from which a chisel is forged is octagonal (eight-sided). Cold chisels are classified according to the shape of their points, and the width of the cutting edge denotes their size. The most common shapes of chisels are flat (cold chisel), cape, round nose, and diamond point. (See fig. 1-1-27.)

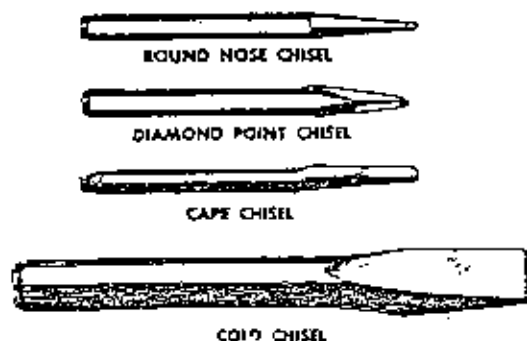


Figure 1-1-27.—Metal-working chisels.

The type chisel most commonly used is the flat cold chisel, which serves to cut rivets, split nuts, chip castings, and cut thin metal sheets. Also used for special jobs is the cape chisel for cutting keyways, narrow grooves and square corners, the round-nose chisel for semi-circular grooves and for chipping inside corners with a fillet, and the diamond-point for cutting V-grooves and sharp corners.

As with other tools there is a correct technique for using a chisel. Select a chisel that is large enough for the job. Be sure to use a hammer that matches the chisel; that is, the larger the chisel, the heavier the hammer. A heavy chisel will absorb the blows of a light hammer and will do virtually no cutting.

As a general rule, hold the chisel in the left hand with the thumb and first finger about 1 inch from the top. It should be held steadily but not tightly. The finger muscles should be relaxed, so if the hammer strikes the hand it will slide down the tool and lessen the effect of the blow. Keep the eyes on the cutting edge of the chisel, not on the head, and swing the hammer in the same plane as the body of the chisel. If you have a lot of chiseling to do, slide a piece of rubber hose over the chisel. This will lessen the shock to your hand.

When using a chisel for chipping, always wear goggles to protect your eyes. If other men are working close by, see that they are protected from flying chips by erecting a screen or shield to contain the chips. Remember that the time to take these precautions is before you start the job.

FILES

There are a number of different types of files in common use, and each type may range in length from 3 to 18 inches. They are graded according to the degree of fineness, and according to whether they are single- or double-cut.

The length of a file is the distance from the tip to the heel, and does not include the tang. (See fig. 1-1-28.)

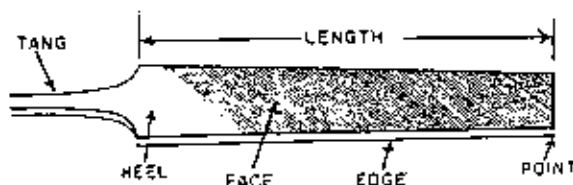


Figure 1-1-28.—File nomenclature.

In selecting a file for a job, the shape of the finished work must be considered. Files come in different shapes, both outline and cross sectional shape. Some of the cross sectional shapes are shown in fig. 1-1-29.

TRIANGULAR files are tapered (longitudinally) on all three sides. They are used to file acute internal angles, and to clear out square corners. Special triangular files are used to file saw teeth.

MILL files are tapered in both width and thickness. One edge has no teeth and is known as a SAFE EDGE. Mill files are used for smoothing lathe work, drawfiling, and other fine, precision work. Mill files are always single-cut.

FLAT files are general-purpose files and may be either single- or double-cut. They are tapered in width and thickness. HARD files, not shown, are somewhat thicker than flat files. They taper slightly in thickness, but their edges are parallel.



Figure 1-1-29.—Cross-sectional shapes of files.

SQUARE files are tapered on all four sides and are used to enlarge rectangular-shaped holes and slots. ROUND files serve the same purpose for round openings. Small round files are often called "rattail" files.

The HALF ROUND file is a general-purpose tool. The rounded side is used for curved surfaces and the flat face on flat surfaces. When you file an inside curve, use a round or half-round file whose curve most nearly matches the curve of the work.

Kits of small files, often called Swiss Pattern or Jewelers files, are used to fit parts of delicate mechanisms, and for filing work on instruments. Handle these small files carefully because they break easily.

Cuts and grades of files vary greatly. As mentioned before, they have either single-cut or double-cut teeth. The difference is apparent when you compare the files in fig. 1-1-30.

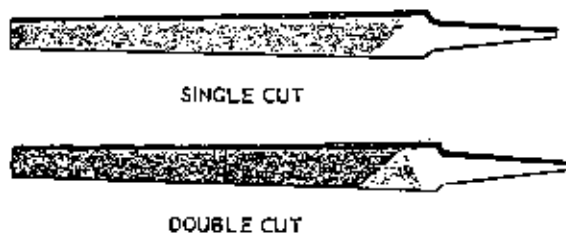


Figure 1-1-30.—Single and double-cut files.

Single-cut files have rows of teeth cut parallel to each other. These teeth are set at an angle of about 65 degrees with the centerline. You will use single-cut files for sharpening tools,

finish filing, and drawfiling. They are also the best tools for smoothing the edges of sheet metal.

Files with crisscrossed rows of teeth are double-cut files. The double cut forms teeth that are diamond-shaped and fast cutting. You will use double-cut files for quick removal of metal, and for rough work.

Files are also graded according to the spacing and size of their teeth, or their coarseness and fineness. Some of these grades are pictured in fig. 1-1-31. In addition to the three grades shown, you may use some DEAD SMOOTH files, which have very fine teeth, and some ROUGH files with very coarse teeth. The fineness or coarseness of file teeth is also influenced by the length of the file. When you have a chance, compare the actual size of the teeth of a 6-inch, single-cut smooth file and a 12-inch, single-cut smooth file; you will notice the 6-inch file has more teeth per inch than the 12-inch file.

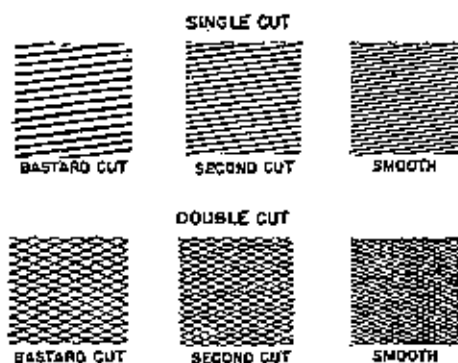


Figure 1-1-31.—Grades of file teeth.

The flat or hand files most often used are the double-cut second cut file for rough work and the single-cut, smooth file for finish work.

For smoothing soft metals, such as aluminum and bearing metal, you may be supplied with a FLOAT-CUT file. It has large curved teeth and is worked with a planing action.

Never use a file unless it is equipped with a tight-fitting handle. If you use a file without the handle and it bumps something or jams to a sudden stop, the tang may be driven into your hand. To put a handle on a file tang, drill a hole in the handle, slightly smaller than the tang. Insert the tang end, and then tap the end of the handle to seat it firmly. Make sure you get the handle on straight.

As you file, the teeth of the file may clog up with some of the metal filings and scratch your work. This condition is known as PINNING. You can prevent pinning by keeping the file teeth clean. Rubbing chalk between the teeth will help prevent pinning, too, but the best method is to clean the file frequently with a FILE CARD or brush. A file card (fig. 1-1-32) has fine wire bristles. Brush with a pulling motion, holding the card parallel to the rows of teeth.

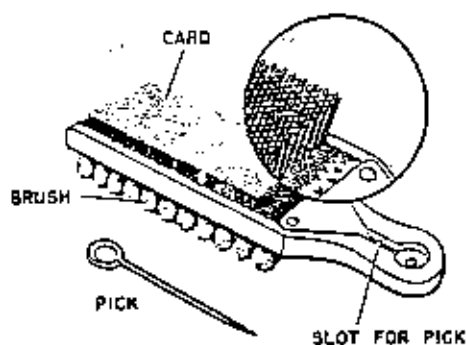


Figure 1-1-32.-File Card.

A new file should be broken in carefully by using it first on brass, bronze, or smooth cast iron. Just a few of the teeth will cut at first, so use a light pressure to prevent tooth breakage. Do not break in a new file by using it first on a narrow surface.

Protect the file teeth by hanging your files in a rack when they are not in use, or by placing them in drawers with wooden partitions. Your files should not be allowed to rust—keep them away from water and moisture. Avoid getting the files oily. Oil causes a file to slide across the work and prevents fast, clean cutting. Files that you keep in your toolbox should be wrapped in paper or cloth to protect their teeth and prevent damage to other tools.

Never use a file for prying or pounding. The tang is soft and bends easily. The body is hard and extremely brittle. Even a slight bend or a fall to the deck may cause a file to snap in two. Do not strike a file against the bench or vise to clean it—use a file card.

TWIST DRILLS

Making a hole in a piece of metal is generally a simple operation, but in most cases is an important and a precise job. A large number of different tools and machines have been designed so that holes may be made speedily, economically, and accurately in all kinds of material.

In order to be able to use these tools efficiently, it is well to become acquainted with them. The most common tool for making holes in metal is the twist drill. It consists of a cylindrical piece of steel with spiral grooves. One end of the cylinder is pointed while the other end is shaped so that it may be attached to a drilling machine. The grooves, usually called FLUTES, may be cut into the steel cylinder, or the flutes may be formed by twisting a flat piece of steel into a cylindrical shape.

The principal parts of a twist drill are the body, the shank, and the point. (See fig. 1-1-33.) The dead center of a drill is the sharp edge at the extreme tip end of the drill. It is formed by the intersection of the cone-shaped surfaces of the point and should always be in the exact center of the axis of the drill. The point of the drill

should not be confused with the dead center. The point is the entire cone-shaped surface at the end of the drill.

The lip or cutting edge of a drill is that part of the point that actually cuts away the metal when drilling a hole. It is ordinarily as sharp as the edge of a knife. There is a cutting edge for each flute of the drill.

The lip clearance of a drill is the surface of the point that is ground away or relieved just back of the cutting edge of the drill. The strip along the inner edge of the body is called the margin. It is the greatest diameter of the drill and extends the entire length of the flute. The diameter of the margin at the shank end of the drill is smaller than the diameter at the point. This allows the drill to revolve without binding when drilling deep holes.

A tang is found only on tapered-shank drills. It is designed to fit into a slot in the socket or spindle of a machine. It may bear a portion of the driving torque, but its principal use is to make it easy to remove the drill from the socket of the driving machine.

The maintenance of twist drills and more about how to use them on specific jobs are discussed in a later section of this text.

REAMERS

Reamers are used to enlarge and true a hole. The reamer consists of three parts—the body, the shank, and the blades. The shank has a square tang to allow the reamer to be held with a wrench for turning. The main purpose of the body is to support the blades.

The blades on a reamer are made of steel and hardened to such an extent that they are brittle. For this reason you must be careful when using and storing the reamer to protect the blades from chipping. When you are reaming a hole, turn the reamer in the CUTTING DIRECTION ONLY. This will prevent chipping or dulling of the blades. Great care should be used to assure even, steady turning. Otherwise, the reamer will chatter, causing the hole to become marked or scored. To prevent damage to the reamer while not in use, wrap it in an oily cloth and keep it in a box.

Reamers of the types shown in figure 1-1-34 are available in any standard size. They are also available in size variations of .001" for special work. Use a solid straight flute reamer when reaming a number of holes of the same size. This type lasts longer and is less expensive than the expansion reamer.

The solid spiral flute reamer is used where many similar holes are to be reamed. Many mechanics prefer it because it is less likely to chatter. The spiral reamer costs slightly more than the straight flute reamer.

For general purposes, an expansion reamer (fig. 1-1-35) is the most practical. This reamer can usually be obtained in standard sizes from 1/4 of an inch to 1 inch, by 32nds. It is designed to allow the blades to expand 1/32 of an inch.

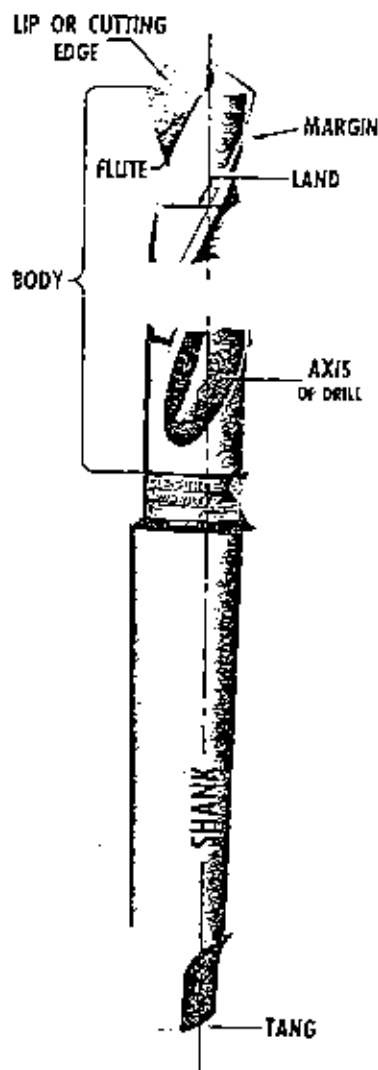


Figure 1-1-33.—Twist drill nomenclature.

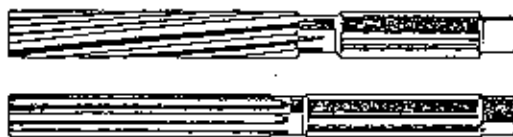


Figure 1-1-34.—Above—solid spiral flute reamer.
Below—solid straight flute reamer.

For example, the 1/4-inch expansion reamer will ream a 1/4-inch to a 9/32-inch hole. A 9/32-inch reamer will enlarge the hole from 9/32 of an inch to 5/16 of an inch. This range of adjustment allows a few reamers to cover sizes up to 1 inch.

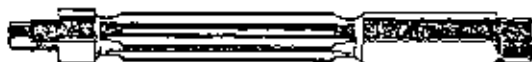


Figure 1-1-35.—Expansion reamer.

Reamers are made of carbon steel and high-speed steel. In general, the cutting blades of a high-speed reamer lose their keenness more quickly than a carbon steel reamer. However, after that keenness is gone, it will last longer than the carbon reamer.

COUNTERSINKS

Countersinking is the operation of beveling the mouth of a hole with a rotary tool called a countersink. (See fig. 1-1-36.) The construction of the countersink is similar to the twist drill. There are four cutting edges, which are taper ground, to the angle marked on the body.



Figure 1-1-36.—Countersink.

A countersink is used primarily to set the head of a screw or rivet flush with the material in which it is being placed. Countersinks are made in a number of sizes. One size usually takes care of holes of several different sizes. That is, the same countersink can be used for holes from 1/4 inch to 1/2 inch in diameter. Remove only enough metal to set the screw or rivet head flush with the material. If you remove too much material the hole will enlarge and weaken the work.

Select the countersink with the correct lip angle to correspond with the screw or rivet head being used. These countersinks can be turned by any machine that will turn a twist drill.

BOLT CUTTERS

Bolt cutters (fig. 1-1-37) are giant shears with very short blades and long handles. The handles are hinged at one end. The cutters are at the ends of extensions which are jointed in such a way that the inside joint is forced outwards when the handles are closed, thus forcing

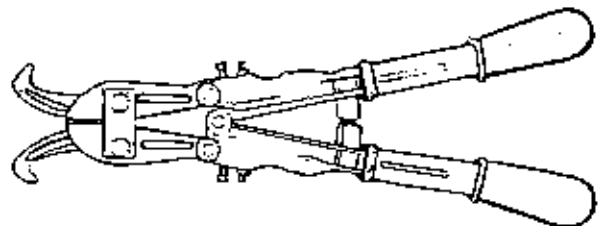


Figure 1-1-37.—Bolt cutters.

the cutting edges together with great force. Bolt cutters are made in lengths of 18 to 36 inches. The larger ones will cut mild steel bolts and rods up to 1/2 inch. The material to be cut should be kept as far back in the jaws as possible.

Never attempt to cut spring wire or other tempered metal with bolt cutters. This will cause the jaws to be sprung or nicked. Adjusting screws near the middle hinges provide a means for ensuring that both jaws move the same amount when the handles are pressed together. Keep the adjusting screws just tight enough to ensure that the cutting edges meet along their entire length when the jaws are closed. The hinges should be kept well oiled at all times.

When using bolt cutters make sure your fingers are clear of the jaws and hinges. Take care that the bolt head or piece of rod cut off does not fly and injure you or someone else. If the cutters are brought together rapidly, sometimes a bolt-head or piece of rod being cut off will fly some distance.

Bolt cutters are fairly heavy, so make sure that they are stored in a safe place where they will not fall and injure someone.

WOODCUTTING HANDTOOLS

A man working with wood uses a large variety of handtools. He should be familiar with these tools, their proper names, the purpose for which they are used, and how to keep them in good condition.

In this section of the text, only the basic woodcutting tools are covered.

HANDBSAWS

The most common carpenter's handsaw consists of a steel blade with a handle at one end. The blade is narrower at the end opposite the handle. This end of the blade is called the point or toe. The end of the blade nearest the handle is called the "heel" (fig. 1-1-38.) One edge of the blade has teeth, which act as two rows of cutters. When the saw is used, these teeth cut two parallel grooves close together. The chips (sawdust) are pushed out from between the grooves (kerf) by the beveled part of the teeth. The teeth are bent alternately to one side or the other, to make the kerf wider than the thickness of the blade. This bending is called the "set" of the teeth. (See fig. 1-1-39.) The number of teeth per inch, the size and shape of the teeth, and the amount of set depend on the use to be made of the saw and the material to be cut. Carpenter's handsaws are described by the number of points per inch. There is always one more point than there are teeth per inch. A number stamped near the handle gives the number of points of the saw.

Woodworking handsaws consist of RIPSaws and CROSSCUT saws designed for general cutting. Ripsaws are used for cutting with the grain and crosscut saws are for cutting across the grain. A variety of other hand-operated saws,

designed to serve special purposes, are designated by particular names, such as BACKSAW, DOVETAIL SAW, COPING SAW, and so on.

The major difference between a rip saw and a crosscut saw is the shape of the teeth. A tooth with a square-faced chisel-type cutting edge, like the rip saw tooth shown in figure 1-1-40, does a good job of cutting with the grain (called ripping), but a poor job of cutting across the grain (called crosscutting). A tooth with a beveled, knifetype cutting edge, like the crosscut saw tooth shown in the same figure, does a good job of cutting across the grain, but a poor job of cutting with the grain.

The more common types of saws used for special purposes are shown in figure 1-1-40. The BACKSAW is a crosscut saw designed for sawing a perfectly straight line across the face of a piece of stock. A heavy steel BACKING along the top of the blade keeps the blade perfectly straight.

The DOVETAIL saw is a special type of backsaw with a thin, narrow blade and a chisel-type handle.

The COMPASS saw is a long, narrow, tapering rip saw designed for cutting out circular or other nonrectangular sections from within the margins of a board or panel. A hole is bored near the cutting line to start the saw. A KEY-HOLE saw is simply a finer, narrower compass saw.

The COPING saw is used to cut along curved lines as shown in the figure.

The TWO-MAN CROSSCUT saw (fig. 1-1-42) is a double-handed saw used for heavy work, such as felling trees, cutting large trees into logs, or sawing heavy bridge timbers. This saw is made of high-grade steel, with an arched blade 5 feet to 6 1/2 feet in length, approximately 8 inches wide at the middle and tapering to about 3 inches at each end. The cutting teeth are grouped in sections, usually with four cutting teeth to the section. Between sections are raker teeth which chisel out and remove the chips.

The two-man saw is operated by each man pulling the saw toward himself as far as it will go and then stopping, only guiding the saw as the other pulls it back. In vertical cutting, the weight of the saw creates enough pressure to make further forcing unnecessary. In horizontal cutting, only slight pressure on the saw is needed. Oil or paraffin on the blade will lubricate the blade and ease the work.

A saw that is not being used should be hung up or stowed in a toolbox. A toolbox designed for holding saws has notches that hold them on edge, teeth up. Stowing saws loose in a toolbox may allow the saw teeth to become dulled or bent by contacting other tools.

Before using a saw, be sure there are no nails or other edge-destroying objects in the line of the cut. When sawing out a strip of waste, do not break out the strip by twisting the saw blade. This dulls the saw, and may spring or break the blade.

Be sure that the saw will go through the full stroke without striking the floor or some other

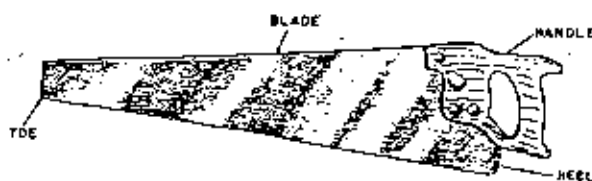


Figure 1-1-38.—Nomenclature of a handsaw.

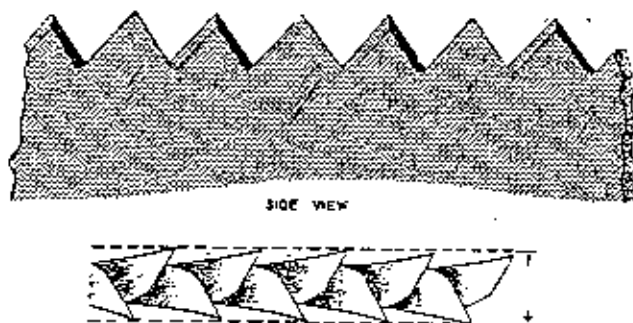
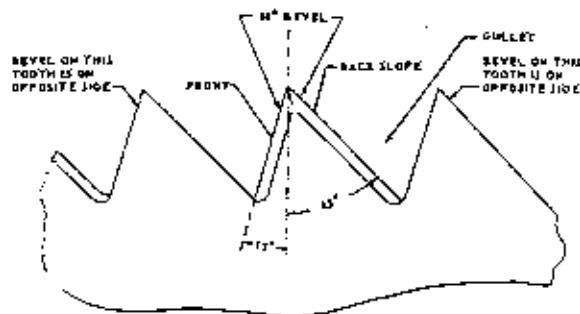
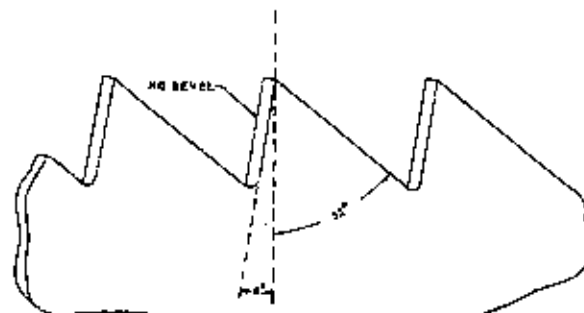


Figure 1-1-39.—"Set" of hand saw teeth.

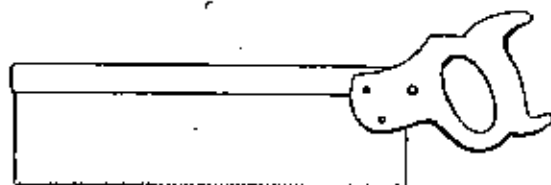


CROSSCUT SAW TEETH

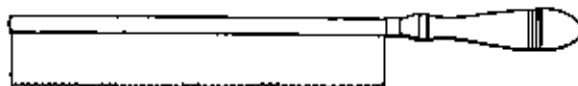


RIPSAW TEETH

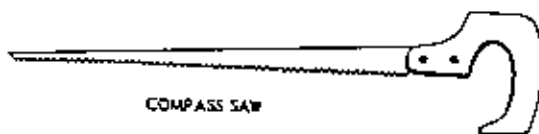
Figure 1-1-40.—Crosscut saw and ripsaw teeth.



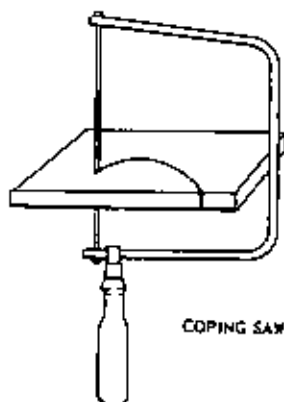
BACK SAW



DOVETAIL SAW



COMPASS SAW



COPING SAW

Figures 1-1-41.—Special saws.

object. If the work cannot be raised high enough to obtain full clearance for the saw, you must carefully limit the length of each stroke.

Some right and wrong methods of using and caring for a saw are shown in figure 1-1-43.

PLANES

The plane is the most extensively used of the hand shaving tools. Most of the lumber handled by anyone working with wood is dressed on all four sides, but when performing jobs such as fitting doors and sash, and interior trim work, planes must be used.

The large family of planes includes BENCH and BLOCK PLANES, designed for general surface smoothing and squaring, and other planes designed for special types of surface work.

The principal parts of a BENCH PLANE and the manner in which they are assembled, are shown in figure 1-1-44. The part at the rear that you grasp to push the plane ahead is called the HANDLE; the part at the front that you grasp to guide the plane along its course is called the KNOB. The main body of the plane, consisting of the bottom, the sides, and the sloping part which carries the plane iron, is called the FRAME. The bottom of the frame is called the SOLE, and the opening in the sole, through which the blade emerges, is called the MOUTH. The front end of the sole is called the TOE; the rear end, the HEEL.

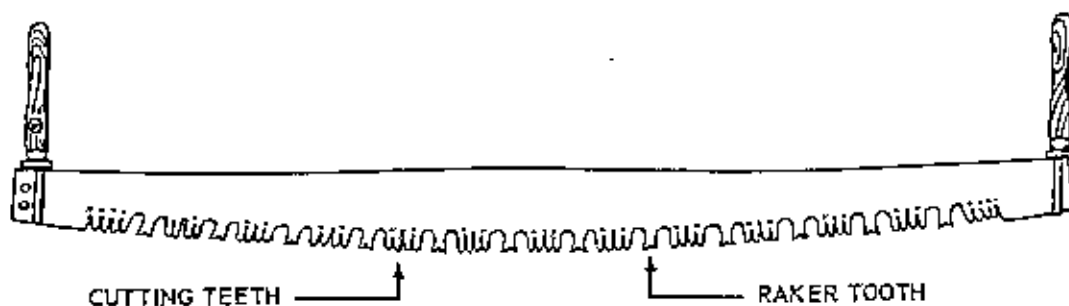


Figure 1-1-42.—Two-man crosscut saw.

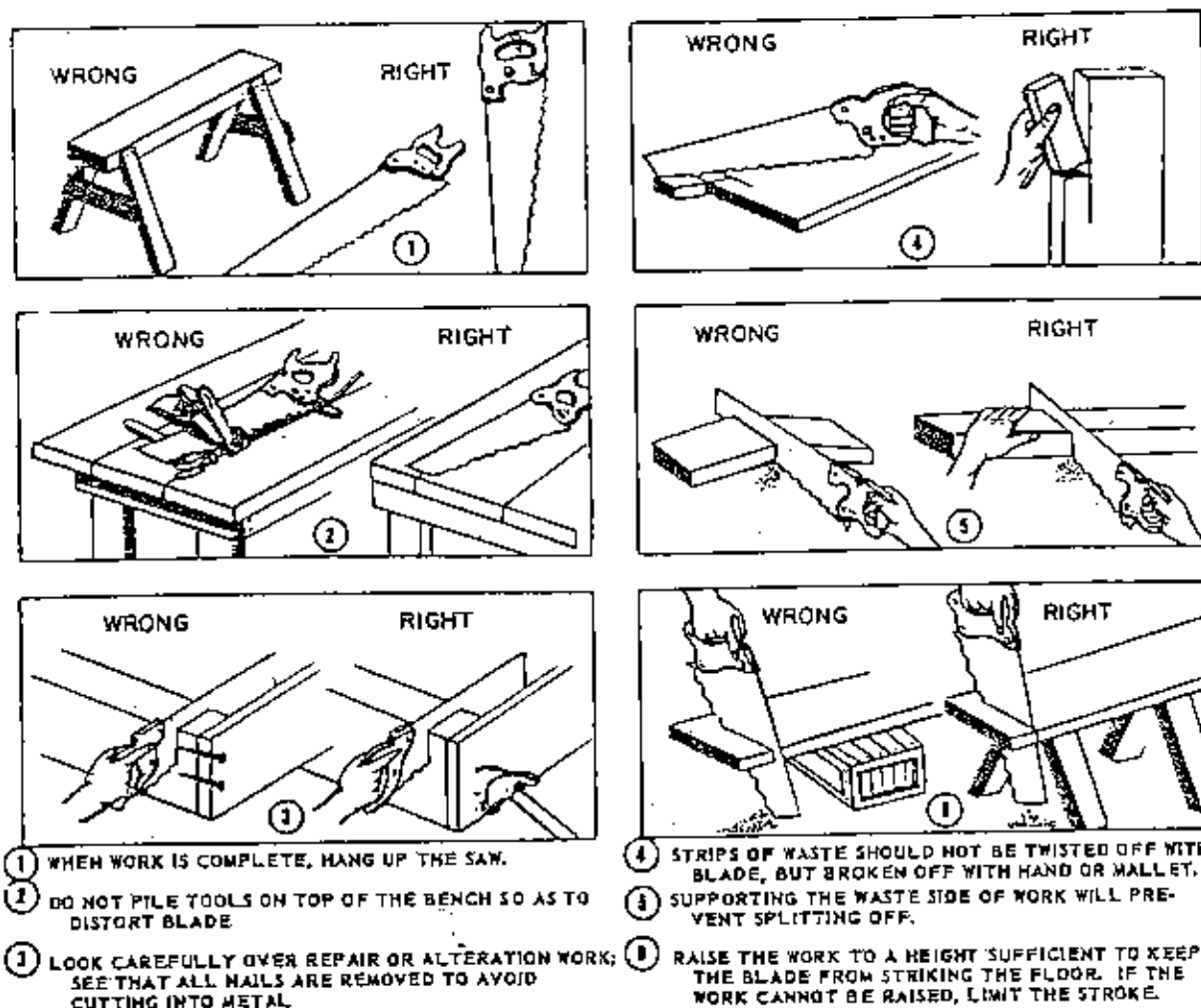


Figure 1-1-43.—Care of handsaws.

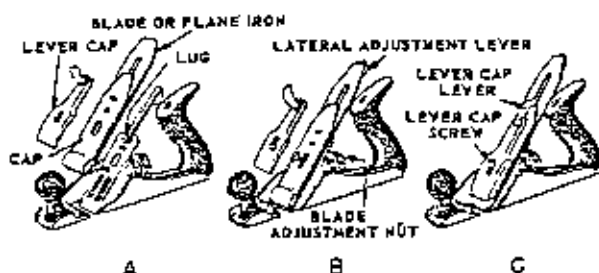


Figure 1-1-44.—Parts of a bench plane.

A PLANE IRON CAP, which is screwed to the upper face of the plane iron, deflects the shaving upward through the mouth, as indicated in figure 1-1-45C, and thus prevents the mouth from becoming choked with jammed shavings. The edge of the cap should fit the back of the iron as shown in figure 1-1-45A, not as shown in figure 1-1-45B. The lower end of the plane iron cap should be set back 1/32 in. from the edge of the plane iron, as shown in figure 1-1-45A. The iron in a bench plane goes in bevel-down.

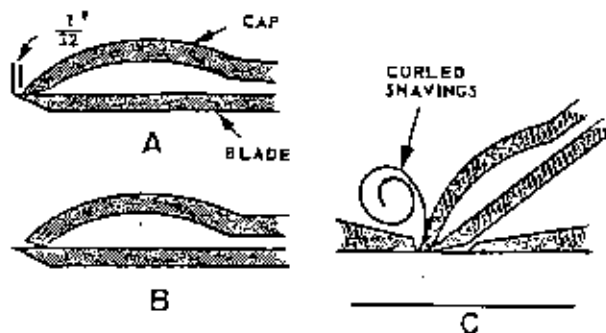


Figure 1-1-45.—Plane iron and plane iron cap.

The edge of the plane iron is brought into correct cutting position by the manipulation of first the ADJUSTING NUT and next the LATERAL ADJUSTMENT LEVER, as shown in figures 1-1-46 and 1-1-47. The adjusting nut moves the edge of the iron up or down; the lateral adjustment lever cants it to the right or left. To adjust the plane you hold it upside-down, sight along the sole from the toe, and work the adjusting nut until the edge of the blade appears. Then work the lateral adjustment lever until the edge of the blade is in perfect alignment with the sole, as shown in figures 1-1-46B and 1-1-46C. Then use the adjusting nut to give the blade the amount of protrusion you want. This amount will depend, of course, upon the depth of the cut you intend to make.

There are three types of bench planes (fig. 1-1-48): the SMOOTH plane, the JACK plane, and the JOINER plane (sometimes called the FORE plane or the GAGE plane). All are used primarily for shaving and smoothing with the grain; the chief difference is the length of the sole. The sole of the smooth plane is about 9 in. long, the sole of the jack plane about 14 in. long, and the sole of the joiner plane from 20 to 24 in. long.

The longer the sole of the plane is, the more uniformly flat and true the planed surface will be. Consequently, which bench plane you should use depends upon the requirements with regard to surface trueness. The smooth plane is, in general, smoother only; it will plane a smooth, but not an especially true surface in a short time. It is also used for cross-grain smoothing and squaring of end-stock.

The jack plane is the general "jack-of-all-work" of the bench plane group. It can take a deeper cut and plane a truer surface than the smooth plane. The joiner plane is used when the planed surface must meet the highest requirements with regard to trueness.

A BLOCK PLANE and the names of its parts are shown in figure 1-1-49. Note that the plane iron in a block plane does not have a plane iron cap, and also that, unlike the iron in a bench plane, the iron in a block plane goes in bevel-up.

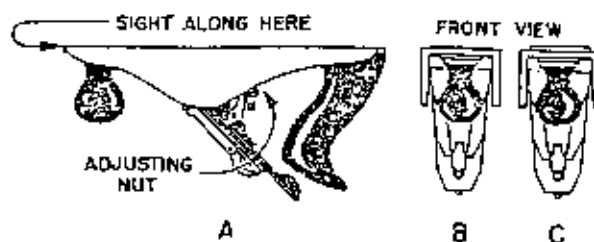


Figure 1-1-46.—Manipulation of the adjusting nut moves the plane iron up or down.

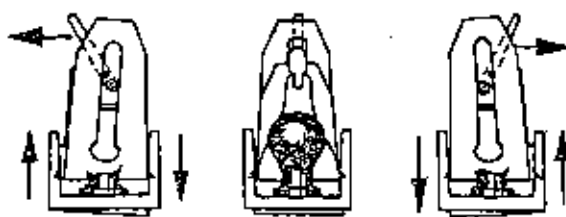


Figure 1-1-47.—Effect of manipulation of the lateral adjustment lever.

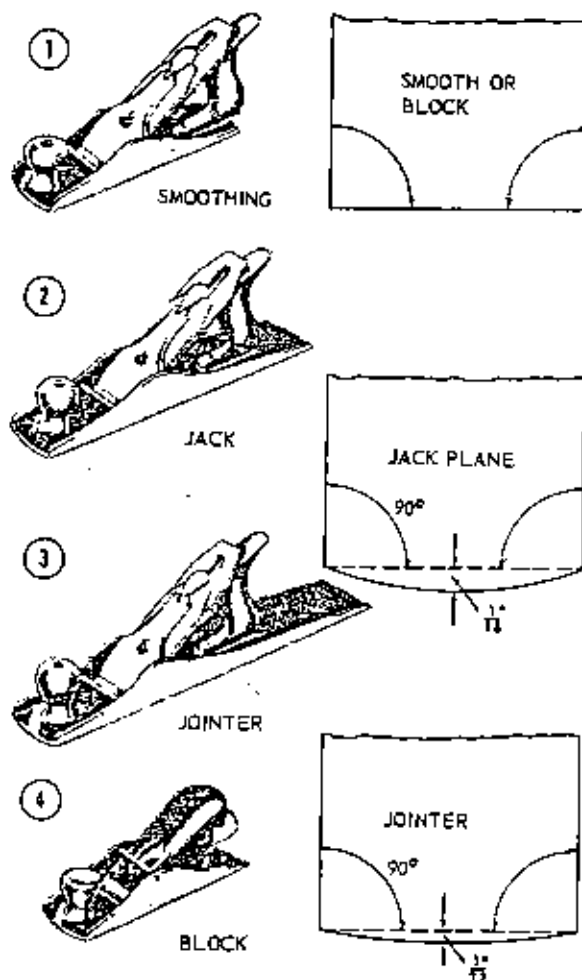


Figure 1-1-48.—Types of bench planes and block plane.

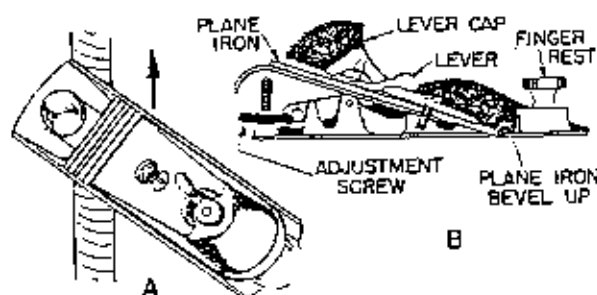


Figure 1-1-49.—Block plane nomenclature.

The block plane, which is usually held at an angle to the work, is used chiefly for cross-grain squaring of end-stock. It is also useful, however, for smoothing all plane surfaces on very small work.

There are a great variety of special-purpose planes, only a few of which can be mentioned here. The RABBIT-AND-FILLISTER plane is used to plane a RABBIT (a groove cut on the edge or end of a piece of board) on an edge, as shown in figure 1-1-50. A FILLISTER is simply a rabbit which has been planed into the outer edge of a window sash bar. Before planing set the WIDTH GAGE on the plane to the desired width of the rabbit, and the DEPTH GAGE to the desired depth. To use this plane, set it on the edge with the width gage against the face of the board, and plane down until the further progress of the plane is stopped by the depth gage. The side edge of the plane iron must be set exactly flush with the side edge of the sole on the plane. The SPUR breaks trail, as it were, for the plane iron. Many rabbit-and-fillister planes do not have the spur.

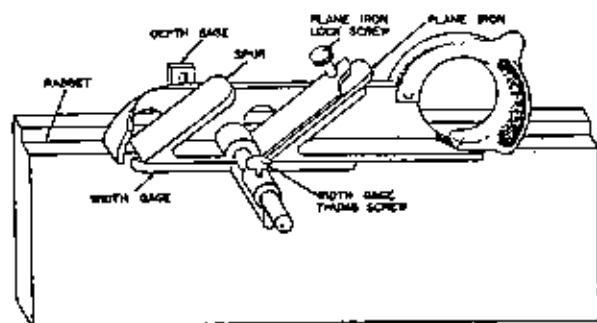


Figure 1-1-50.—Rabbit-and-fillister plane.

The ROUTER plane (fig. 1-1-51) is used to smooth the bottom of a groove that has been roughed out with a chisel. The way the plane works is evident in the illustration.

A BULL-NOSE plane is a small one-hand plane with the mouth located near the forward edge of the sole and the iron flush with one or both sides of the sole; it is used for planing close into corners. A PLOW plane uses irons of different widths. A UNIVERSAL plane is a com-

plicated tool which is equipped with cutters of various shapes for planing moldings. A MATCHING PLANE cuts a groove on one piece and a tongue to "match" it on another.

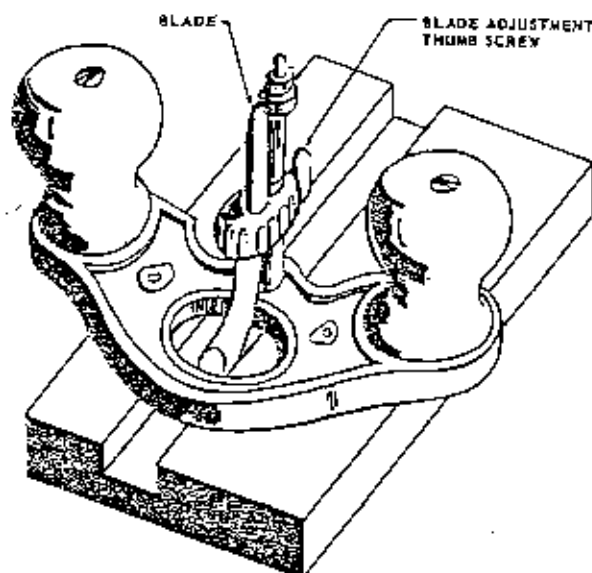


Figure 1-1-51.—Router plane.

AUGER BITS

The woodworking and metal trades distinguish sharply between bits and drills and between boring and drilling. A woodworker never says that a hole is drilled in wood, but uses the term "bored" instead.

Bits are used for boring holes for screws, dowels, and hardware, as an aid in mortising (cutting a cavity in wood for joining members) and in shaping curves and for many other purposes. Like saws and planes, bits vary in shape and structure with the type of job to be done. Some of the most common bits are described in this section.

AUGER bits are screw-shaped tools consisting of six parts: the cutter, screw, spur, twist, shank, and tang. (See fig. 1-1-52.) The twist ends with two sharp points called the spurs, which score the circle, and two cutting edges which cut shavings within the scored circle. The screw centers the bit and draws it into the wood. The threads of the screw are made in three different pitches: steep, medium, and fine. The steep pitch makes for quick boring and thick chips, and the fine or slight pitch makes for slow boring and fine chips. For end-wood boring, a steep- or medium-pitch screw bit should be used because end wood is likely to be forced in between the fine screw threads, and that will prevent the screw from taking hold. The twist carries the cuttings away from the cutters and deposits them in a mound around the hole.

The sizes of auger bits are indicated in sixteenths of an inch and are stamped on the tang. A number 10 stamped on the tang means 10/16

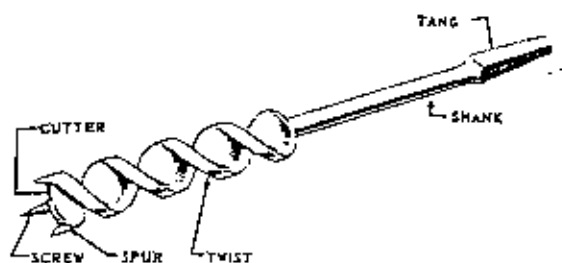


Figure 1-1-52.—Nomenclature of an auger bit, or 5/8 in.; number 5 means 5/16 in. and so on. The most common woodworkers auger bit set ranges in size from 1/4 to 1 in.

Ordinary auger bits up to 1 in. in diameter are from 7 to 9 inches long. Short auger bits that are about 3 1/2 inches long are called DOWEL bits.

EXPANSIVE auger bits have adjustable cutters, for boring holes of different diameters (fig. 1-1-53.) Expansive bits are generally made in two different sizes. The largest size has three cutters and bores holes up to 4 inches in diameter. A scale on the cutter blade indicates the diameter of the hole to be bored.

More will be said on the maintenance, and the use of auger bits for specific jobs in a later section of this book.

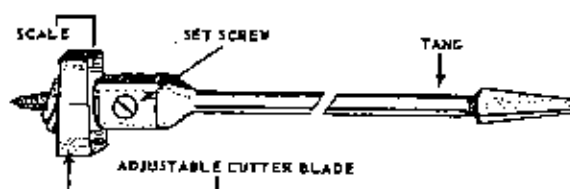


Figure 1-1-53.—Expansion auger bit.

WOOD CHISELS

After a board has been sawed and planed to size, the next operation usually is to join it to another board or part of a structure. A wood chisel, figure 1-1-54, in conjunction with other tools, is indispensable when making most joints by hand.

A wood chisel is a steel tool fitted with a wooden or plastic handle. It has a single beveled cutting edge on the end of the steel part, or blade. According to their construction, chisels may be divided into two general classes: TANG chisels, in which part of the chisel enters the handle, and SOCKET chisels, in which the handle enters into a part of the chisel. (See fig. 1-1-54.)

A socket chisel is designed for striking with a wooden mallet (never a steel hammer), while a tang chisel is designed for hand manipulation only.

Wood chisels are also divided into types, depending upon their weights and thicknesses,

the shape or design of the blade, and the work they are intended to do.

The shapes of the more common types of wood chisels are shown in figure 1-1-55. The FIRMER chisel has a strong, rectangular-cross-section blade, designed for both heavy and light work. The blade of the PARING chisel is relatively thin, and is beveled along the sides for the fine paring work. The BUTT chisel has a short blade, designed for work in hard-to-get-at places.

The butt chisel is commonly used for chiseling the GAINS (rectangular depressions) for the BUTT hinges on doors; hence the name. The MORTISING chisel has a narrow blade, designed for chiseling out the deep, narrow MORTISES for mortise-and-tenon joints. This work requires a good deal of levering out of chips; consequently, the mortising chisel is made extra thick in the shaft to prevent breaking.

A FRAMING chisel is shaped like a firmer chisel, but has a very heavy, strong blade, designed for work in rough carpentry.

Sections 5 and 6 of this course give you more on the maintenance and use of the wood chisel.

SCREWDRIVERS

A screwdriver is one of the most basic of basic handtools. It is also the most frequently abused of all handtools. It is designed for one function only—to drive and remove screws. A screwdriver should not be used as a pry bar, a scraper, a chisel, or a punch.

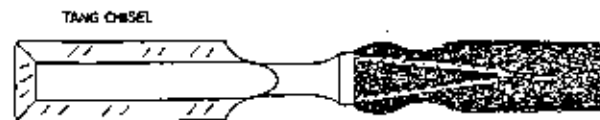
STANDARD SCREWDRIVER

There are three main parts to a standard screwdriver. The portion you grip is called the handle, the steel portion extending from the handle is the shank, and the end which fits into the screw is called the blade. (See fig. 1-1-56.)

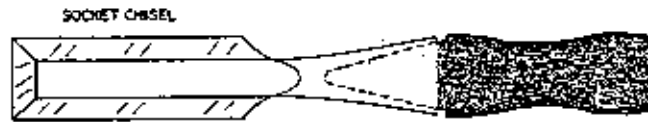
The steel shank is designed to withstand considerable twisting force in proportion to its size, and the tip of the blade is hardened to keep it from wearing. There are times when a screwdriver may be used for gently levering two pieces apart, but you must remember that the shank is not designed to withstand severe bending and the hardened blade will easily break.

Standard screwdrivers are classified by size, according to the combined length of the shank and blade. The most common sizes range in length from 2 1/2 in. to 12 in. There are many screwdrivers smaller and some larger for special purposes. The diameter of the shank, and the width and thickness of the blade are generally proportionate to the length, but again there are special screwdrivers with long thin shanks, short thick shanks, and extra wide or extra narrow blades.

Screwdriver handles may be wood, plastic, or metal. When metal handles are used, there is

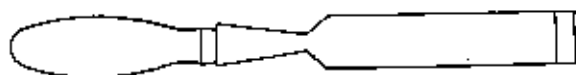


THE SHANK OF THE CHISEL HAS A POINT THAT IS STUCK INTO THE HANDLE. THE POINT IS CALLED A TANG AND THE CHISEL IS CALLED A TANG CHISEL.

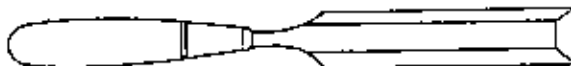


IF THE SHANK OF THE CHISEL IS MADE LIKE A CUP, THE HANDLE WILL FIT INTO IT. THIS IS CALLED A SOCKET CHISEL.

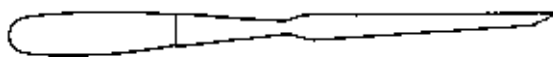
Figure 1-1-54.—Tang and socket wood chisels.



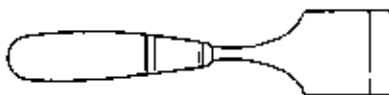
SOCKET FIRMER CHISEL



TANG PARING CHISEL



MORTISING CHISEL



BUTT CHISEL

Figure 1-1-55.—Shapes of common types of wood chisels.

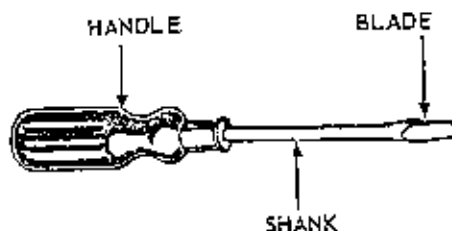


Figure 1-1-56.—Nomenclature of a screwdriver.

usually a wooden hand grip placed on each side of the handle. In some types of wood- or plastic-handled screwdrivers the shank extends through the handle, while in others the shank enters the handle only a short way and is pinned to the handle. For heavy work, special types of screwdrivers are made with a square shank. They are designed this way so that they may be gripped with a wrench, but this is the only kind on which a wrench should be used.

When using a screwdriver it is important to select the proper size so that the blade fits the screw slot properly. This prevents burring the slot and reduces the force required to hold the driver in the slot.

PHILLIPS SCREWDRIVER

Recessed-head screws are now available under various trade names. These have a cavity of special shape formed in the head and require a specially shaped screwdriver. The most common type found is the Phillips head screw that requires a Phillips-type screwdriver. (See fig. 1-1-57.)

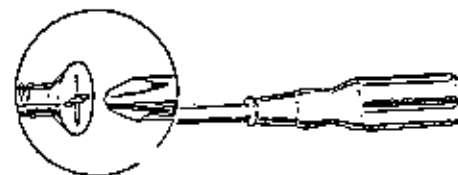


Figure 1-1-57.—Phillips-head screwdriver.

The head of a Phillips-type screw has a four-way slot into which the screwdriver fits. This prevents the screwdriver from slipping. Three standard sized Phillips screwdrivers

handle a wide range of screw sizes. Their ability to hold helps to prevent damaging the slots or the work surrounding the screw. It is a poor practice to try to use a standard screwdriver on a Phillips screw because both the tool and screw slot will be damaged.

OFFSET SCREWDRIVER

The offset screwdriver is a handy tool for use in a tight spot. It is somewhat difficult to handle because the bit has a tendency to jump out of the slot and to burr the screw or surrounding work, if you are not careful. The offset screwdriver has one blade forged in line with the shank or handle and the other blade at right angles to the shank. (See fig. 1-1-58.) With such an arrangement, when the swinging space for the screwdriver is limited, you can change ends after each swing and thus work the screw in or out of the threaded hole. This type screwdriver is to be used when there is not sufficient space to use a standard screwdriver.



Figure 1-1-58.—Offset screwdriver.

RATCHET SCREWDRIVER

For fast easy work the ratchet screwdriver is extremely convenient, as it can be used one-handed and does not require the bit to be lifted out of the slot after each turn. It may be fitted with either a standard type bit or a special bit for recessed heads. The ratchet screwdriver is most commonly used by the woodworker for driving screws in soft wood.

A WORD OF CAUTION

You should never use a screwdriver to check an electrical circuit where the amperage is high. The current may be strong enough to arc and melt the screwdriver blade. And, never try to turn a screwdriver with a pair of pliers.

Do not hold work in your hand while using a screwdriver—if the point slips it can cause a bad cut. Hold the work in a vise, with a clamp, or on a solid surface. If that is impossible, you will always be safe if you follow this rule: NEVER GET ANY PART OF YOUR BODY IN FRONT OF THE SCREWDRIVER BLADE TIP. That is a good safety rule for any sharp or pointed tool.

PLIERS

The word PLIERS is a plural name for a single tool. Pliers are made in many styles and sizes and are used to perform many different operations. There is a definite field of usefulness for pliers, but they are emphatically not a substitute for a wrench. Pliers are used for holding and gripping small articles in situations where it may be inconvenient or impossible to use hands.

SLIP-JOINT PLIERS

Slip-joint pliers (fig. 1-1-59) are pliers with straight, serrated (grooved) jaws, and the screw or pivot with which the jaws are fastened together may be moved to either of two positions, in order to grasp small- or large-sized objects better.

To spread the jaws of slip-joint pliers, first spread the ends of the handles apart as far as possible. The slip-joint, or pivot, will not move to the open position. To close, again spread the handles as far as possible, then push the joint back into the closed position.



Figure 1-1-59.—Slipjoint pliers.

Slip-joint combination pliers (fig. 1-1-60) are pliers similar to the slip-joint pliers just described, but with the additional feature of a side cutter at the junction of the jaws. This cutter consists of a pair of square cut notches, one on each jaw, which act like a pair of shears when an object is placed between them and the jaws are closed.

The cutter is designed to cut material such as soft wire and nails. To use the cutter, open



Figure 1-1-60.—Slipjoint combination pliers.

the jaws until the cutter on either jaw lines up with the other. Place the material to be cut as far back as possible into the opening formed by the cutter, and squeeze the handles of the pliers together. Do not attempt to cut hard material such as spring wire or hard rivets with the combination pliers. To do so will spring the jaws; and if the jaws are sprung, it will be difficult thereafter to cut small wire with the cutters.

WISE-GRIP PLIERS

Vise-Grip pliers (wrenches) can be used for holding objects regardless of their shape. A screw adjustment in one of the handles makes them suitable for several different sizes. The jaws of Vise-Grips may have standard serrations such as the pliers just described or may have a clamp-type jaw. The clamp-type jaws are generally wide and smooth and are used primarily when working with sheet metal.

Vise-Grip pliers have an advantage over other types of pliers in that you can clamp them on an object and they will stay. This will leave your hands free for other work.

WATER-PUMP PLIERS

Water-pump pliers were originally designed for tightening or removing water pump packing nuts. They were excellent for this job because they have a jaw adjustable to seven different positions. Water-pump pliers (fig. 1-1-61) are easily identified by their size, jaw teeth, and adjustable slip joint. The inner surface of the jaws consists of a series of coarse teeth formed by deep grooves, a surface adapted to grasping cylindrical objects.

Another version of the water-pump pliers is called Channel-Lock pliers. They are shaped approximately the same as the pliers just described, but the jaw opening adjustment is



Figure 1-1-61.—Water pump pliers.

effected differently. Channel-Lock pliers have grooves on one jaw and lands on the other. The adjustment is effected by changing the position of the grooves and lands. The Channel-Lock pliers are less likely to slip from the adjustment setting when gripping an object.

DIAGONAL PLIERS

Diagonal cutting pliers (fig. 1-1-62) are used for cutting small, light material, such as

wire and cotter pins in areas which are inaccessible to the larger cutting tools. Also, since they are designed for cutting only, larger objects can be cut than with the slip-joint pliers.

As the cutting edges are diagonally offset approximately 15 degrees, diagonal pliers are adapted to cutting small objects flush with a surface. The inner jaw surface is a diagonal straight cutting edge. Diagonal pliers should never be used to hold objects, because they exert a greater shearing force than other types of pliers of a similar size. The sizes of the diagonal cutting pliers are designated by the overall length of the pliers.

SIDE CUTTING PLIERS

Side-cutting pliers (sidecutters) are principally used for holding, bending, and cutting thin materials or small gage wire. Sidecutters vary in size and are designated by their overall length. The jaws are hollowed out on one side just forward of the pivot point of the pliers. Opposite the hollowed out portion of the jaws are the cutting edges.

When holding or bending light metal surfaces, the jaw tips are used to grasp the object. When holding wire grasp it as near one end as possible because the jaws will mar the wire. To cut small diameter wire the side cutting edge of the jaws near the pivot is used. Never use sidecutters to grasp large objects, tighten nuts, or bend

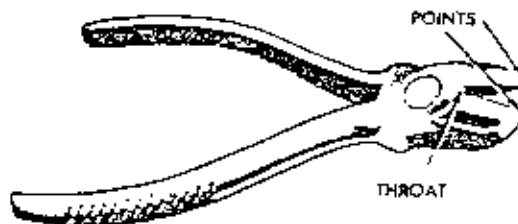


Fig. 1-1-62.—Diagonal-cutting pliers.

heavy gage metal, since such operations will spring the jaws.

Sidecutters are often called electrician or lineman pliers. They are used extensively for stripping insulation from wire and for twisting wire when making a splice.

MAINTENANCE OF PLIERS

Nearly all sidecutting pliers and diagonals are designed so that the cutting edges can be reground. Some older models of pliers will not close if material is ground from the cutting edges. When grinding the cutting edges never take any more material from the jaws than is necessary to remove the nicks. Grind the same amount of stock from both jaws.

NOTE: When jaws on pliers do not open enough to permit grinding, remove the pin that attaches the two halves of the pliers so that the jaws can be separated.

The serrations on the jaws of pliers must be sharp. When they become dull, the pliers should be held in a vise and the serrations recut by using a small 3-corner file.

Pliers should be coated with light oil when they are not in use. They should be stored in a toolbox in such a manner that the jaws cannot be injured by striking hard objects. Keep the pin or bolt at the hinge just tight enough to hold the two parts of the pliers in contact and always keep the pivot pin lubricated with a few drops of light oil.

PUNCHES

A hand punch is a tool that is held in the hand and struck on one end with a hammer. There are many kinds of punches designed to do a variety of jobs. Most punches are made of tool steel. The part held in the hand is usually octagonal shaped, or it may be knurled. This prevents the tool from slipping around in the hand. The other end is shaped to do a particular job. Figure 1-1-63 shows some of the most commonly used metal punches.

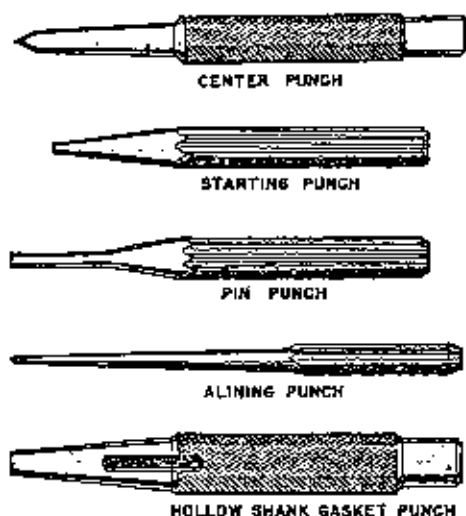


Figure 1-1-63.—Commonly used punches.

METAL PUNCHES

DRIFT punches, sometimes called "starting punches," have a long taper from the tip to the body. They are made that way to withstand the shock of heavy blows. They may be used for knocking out rivets after the heads have been chiseled off, or for freeing pins which are "frozen" in their holes.

After a pin has been loosened or partially driven out, the drift punch may be too large to finish the job. The followup tool to use is the **PIN PUNCH**. It is designed to follow through the

hole without jamming. Always use the largest drift or pin punch that will fit the hole. These punches usually come in sets of three to five assorted sizes. Both of these punches will have flat points, never edged or rounded.

To remove a bolt or pin that is extremely tight, start with a drift punch that has a point diameter that is slightly smaller than the diameter of the object you are removing. As soon as it loosens, finish driving it out with a pin punch. Never use a pin punch for starting a pin because it has a slim shank and a hard blow may cause it to bend or break.

Another punch you will use a lot is the center punch. As the name implies, it is used for marking the center of a hole to be drilled. If you try to drill a hole without first punching the center, the drill will "wander" or "walk away" from the desired center. Another use of the center punch is to make corresponding marks on two pieces of an assembly to permit reassembly in the original positions.

The point of a center punch is accurately ground central with the shank, usually at a 60-degree angle, and is difficult to regrind by hand with any degree of accuracy. It is, therefore, advisable to take care of a center punch and not to use it on extremely hard materials.

Automatic center punches are useful for layout work. They are operated by pressing down on the shank by hand. An inside spring is compressed and released automatically, striking a blow on the end of the punch. The impression is light, but adequate for marking, and serves to locate the point of a regular punch when a deeper impression is required.

For assembling units of a machine an **alining** (alining) punch is invaluable. It is usually about 1 foot long and has a long gradual taper. Its purpose is to line up holes in mating parts.

Hollow metal cutting punches are made from hardened tool steel. They are made in various sizes and are used to cut holes in light gage sheet metal.

Other punches have been designed for special uses. One of these is the soft-faced drift. It is made of brass or fiber and is used for such jobs as removing shafts, bearings, and wrist pins from engines. It is generally heavy enough to resist damage to itself, but soft enough not to injure the finished surface on the part that is being driven.

GASKET PUNCHES

You may have to make gaskets of rubber, cork, leather, or composition materials. For cutting holes in gasket materials a hollow shank gasket punch may be used. Gasket punches come in sets of various sizes to accommodate standard bolts and studs. The cutting end is tapered to a sharp edge to produce a clean, uniform hole. To use the gasket punch, place the gasket material to be cut on a piece of hard wood or lead so that the cutting edge of the punch will not be damaged.

Then strike the punch with a hammer, driving it through the gasket where holes are required.

MEASURING TOOLS

The ability to lay out work and to measure accurately depends upon the correct use of measuring tools and the ease with which the graduations on these tools are read. While each of the measuring tools explained in this section is used for a specific purpose, they are all graduated according to the same system of linear measure.

There are many different types of measuring tools in use. Where exact measurements are required a micrometer caliper (mike) is used. Such a caliper when properly used, gives measurements to within .0001 of an inch accuracy. The common rule or tape will suffice for most measurements that you will need.

RULES AND TAPES

Figure 1-1-64 shows some of the types of rules and tapes commonly used. Of all measuring tools, the simplest and most common is the steel rule. This rule is usually 6 or 12 inches, although other lengths, such as 4 in., 18 in., and longer, are available. Steel rules may be flexible or nonflexible, but the thinner the rule, the easier it is to measure accurately because the division marks are closer to the work.

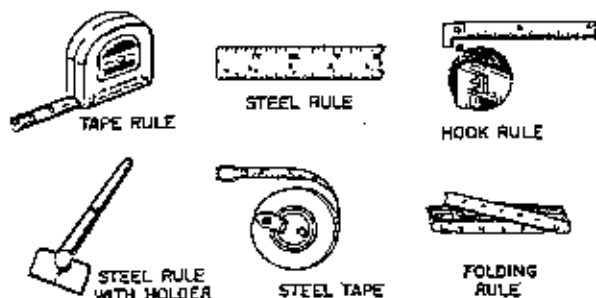


Figure 1-1-64.—Some common types of rules.

Generally a rule has four sets of graduations, one on each edge of each side. The longest lines represent the inch marks. On one edge, each inch is divided into 8 equal spaces; so each space represents 1/8 in. The other edge of this side is divided into sixteenths. The 1/4-in. and 1/2-in. marks are commonly made longer than the smaller division marks to facilitate counting, but the graduations are not, as a rule, numbered individually, as they are sufficiently far apart to be counted without difficulty. The opposite side is similarly divided into 32 and 64 spaces per inch, and it is common practice to number every fourth division for easier reading.

There are many variations of the common rule. Sometimes the graduations are on one side only, sometimes a set of graduations is added across one end for measuring in narrow spaces, and sometimes only the first inch is divided into 64ths, with the remaining inches divided into 32nds and 16ths.

For measuring lengths greater than 18 in., folding steel, wood, or aluminum rules can be used. These are called folding rules and are usually 2 to 6 feet long. The folding rules cannot be relied on for extremely accurate measurements because a certain amount of play develops at the joints after they have been used for a while.

Steel tapes are made from 6 to about 100 ft. in length. In the shorter lengths, these are frequently made with a curved cross section so that they are flexible enough to roll up, but remain rigid when extended. Long, flat tapes require support over their full length when measuring, or the natural sag will cause an error in reading.

The flexible-rigid tapes are usually contained in metal cases into which they wind themselves when a button is pressed, or into which they can be easily pushed. A hook is provided at one end to hook over the object being measured so one man can handle it without assistance. On some models, the outside of the case can be used as one end of the tape when measuring inside dimensions.

Rules and tapes should be handled carefully and kept lightly oiled to prevent rust. Never allow the edges of measuring devices to become nicked by striking them with hard objects. They should preferably be kept in a wooden box when not in use.

To avoid kinking tapes, pull them straight out from their cases—do not bend them backward. With the windup type, always turn the crank clockwise—turning it backward will kink or break the tape. With the spring-wind type, guide the tape by hand. If it is allowed to snap back, it may be kinked, twisted, or otherwise damaged.

SIMPLE CALIPERS

Simple calipers are used in conjunction with a scale to measure diameters. The calipers most commonly used are shown in fig. 1-1-65.

Outside calipers for measuring outside diameters are bow-legged; those used for inside diameters have straight legs with the feet turned called firm-joint calipers. These calipers are adjusted by pulling or pushing the legs to open or close them. Fine adjustment is made by tapping one leg lightly on a hard surface to close them, or by turning them upside down and tapping on the joint end to open them. A variant of the firm-joint has a small screw for making fine adjustments.

Spring-joint calipers have the legs joined by a strong spring hinge and linked together by a screw and adjusting nut.

For measuring chamfered cavities, or for use over flanges, transfer calipers are available. They are equipped with a small auxiliary leaf attached to one of the legs by a screw. (See fig. 1-1-65.) The measurement is made as with ordinary calipers; then the leaf is locked to the leg. The legs may be opened or closed as needed to clear the obstruction, then brought back and locked to the leaf again, thus restoring them to the original setting.

A different type of caliper is the hermaphrodite, sometimes called odd-leg caliper. This has one straight leg ending in a sharp point, sometimes removable, and one bow leg. The hermaphrodite caliper is used chiefly for locating the center of a shaft, or for locating a shoulder.

Keep calipers clean and lightly oiled, but do not overoil the joint of firm joint calipers or you may have difficulty in keeping them tight. Do not throw them around or use them for screwdrivers or pry bars. Remember they are measuring instruments and must be used only for the purpose for which they are intended.

CALIPER SQUARE

The main disadvantage to ordinary calipers is that they do not give a direct reading. It is necessary to measure across the points of a caliper with an ordinary scale to get the measurement. To overcome this, the caliper square, (fig. 1-1-66) sometimes called a slide caliper, is available.

Slide calipers can be used for measuring outside, inside, and other dimensions. One side of the caliper is used as a measuring rule, while the scale on the opposite side is used in measuring outside and inside dimensions. Graduations on both scales are in inches and fractions thereof. A locking screw is incorporated to hold the slide caliper jaws in position during use. Stamped on the frame are two words, "IN" and "OUT," to be used in reading the scale while making inside and outside measurements, respectively.

Pocket slide calipers are commonly made in 3-in. and 5-in. sizes and are graduated to read in 32nds and 64ths. Pocket slide calipers are valuable when extreme precision is not required. They are frequently used for duplicating work when the expense of fixed gages is not warranted.

VERNIER SCALE

When extreme accuracy and close tolerances are needed, measuring tools that incorporate a vernier scale may be used.

The fundamental idea behind the vernier scale is to divide a line of known length into equal parts, and to compare the length of each part with those on a line the same length as the first one, but divided into one less part.

Figure 1-1-67 shows a bar 1 inch long divided by graduations into 40 parts so that each graduation indicates one-fortieth of an inch (0.025 inch). Every fourth graduation is numbered; each number indicates tenths of an inch (4X0.025 inch). The vernier, which slides along the bar, is graduated into 25 divisions which together, are as long as 24 divisions on the bar. Consequently, each division of the vernier is 0.001 inch smaller than each division on the bar. Verniers that are calibrated as just explained are known as English-measure verniers. The metric-measure vernier is read the same, except that the units of measurement are in millimeters, and the fractions are all decimal fractions.

One of the most common applications of the vernier scale is the vernier caliper.

VERNIER CALIPER

Perhaps the most distinct advantage of the vernier caliper is the ability to provide very accurate measurements over a large range. It can be used for both internal and external surfaces. Pocket models usually measure from zero to 3 in., but sizes are available all the way to 4 ft.

A vernier caliper (fig. 1-1-69) consists of an L-shaped member with a scale engraved on the long shank. A sliding member is free to move on the bar and carries a jaw which matches the arm of the L. The vernier scale is engraved on a small plate that is attached to the sliding member.

READING A VERNIER CALIPER

Figure 1-1-69 A illustrates the English measure vernier caliper. Figure B shows an enlarged view of the vernier used. As you can see in this figure, when the zero on the vernier coincides with the 1-inch mark, no other lines coincide until the 25th mark on the vernier. Now count the division on the inch rule. There are only 24 such divisions (each equal to 1/40 inch) opposite the 25 divisions on the vernier. This means that the vernier divisions are a little narrower than those on the rule. Since each of the 24 spaces on the rule equals 1/40" the whole vernier scale is 24 X 1/40" or 24 X 0.0025 = 0.600". Thus one division on the vernier equals 1/25 of 0.600", or 0.024". So, the difference between a division on the vernier and on the rule is 0.025" - 0.024" = 0.001". When measuring, therefore, for each division on the vernier, count from its zero point to the line which coincides with a line on the rule, and to the reading on the rule at this point, add 0.001".

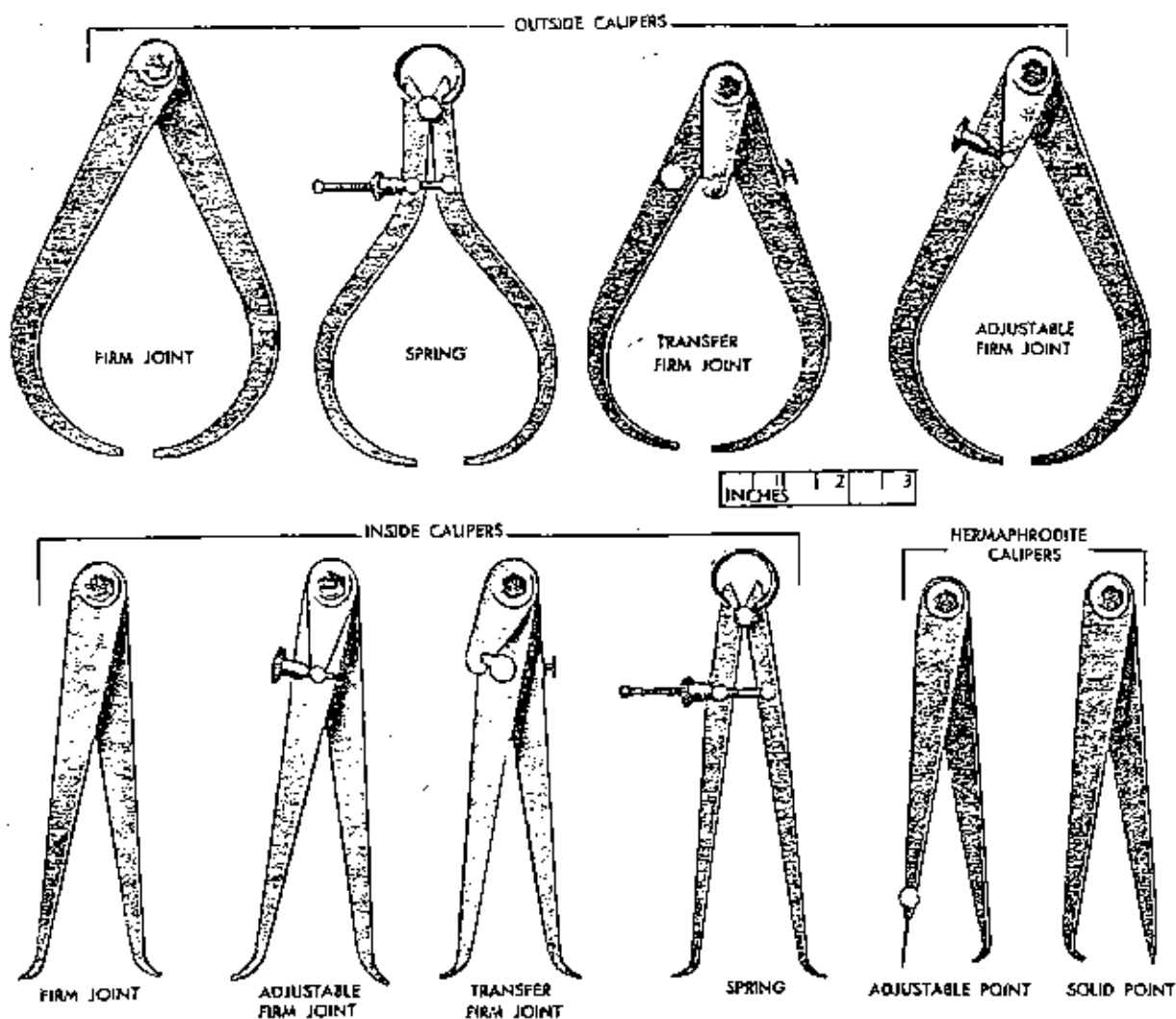


Figure 1-1-65.—Simple calipers—noncalibrated.

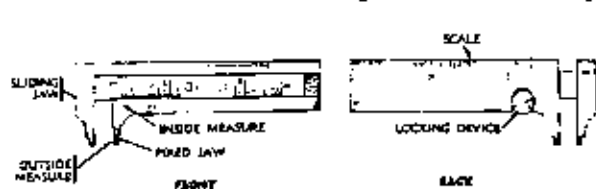


Figure 1-1-66.—Caliper square (slide caliper).



Figure 1-1-67.—English-measure vernier scale.

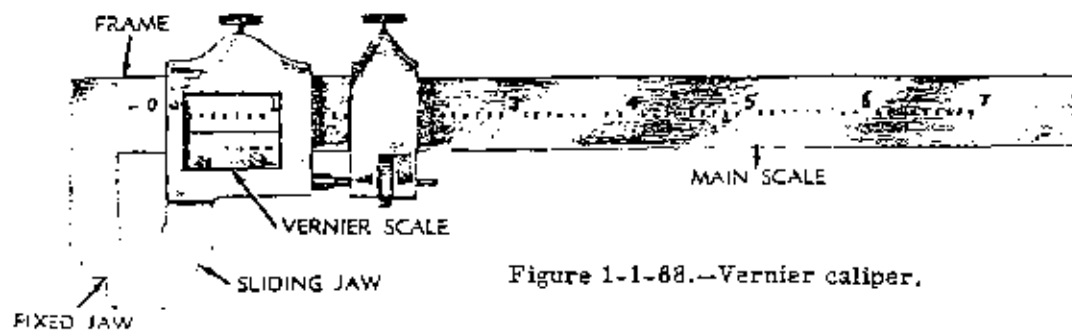


Figure 1-1-68.—Vernier caliper.

To read the caliper in figure 1-1-69C, write down in a column the number of inches (1.000"), of tenths of an inch (0.400"), and of thousandths of an inch the zero mark on the vernier is from the zero mark on the rule. Because the zero mark on the vernier is a little past a 0.025" mark, write down the 0.025" and then note the highest number on the vernier where a line on the vernier coincides with one on the rule. In this case (fig. 1-1-69C) it is at the 0.011" line on the vernier, so you also write the 0.011" in the column which will then look like this:

1.000"
.400"
.025"
.011"

1.436"

The reading on the caliper shown in figure 1-1-69 C is 1.436", and was obtained by adding four separate "readings." After a little practice you will be able to make these calculations mentally.

Now try to read the settings of the two verniers shown in figure 1-1-69 D. Follow the above procedure. You should read 2.350" on the first setting and 2.368" on the second one.

To read a metric-measure vernier, note the number of millimeters, and the 0.25 millimeter if the setting permits, that the zero on the vernier has moved from the zero on the scale. Then add the number of hundredths of a millimeter indicated by the line on the vernier that coincides with a line on the scale.

For example, figure 1-1-70 A shows the zero graduation on the vernier coinciding with a 0.5-mm. graduation on the scale. This indicates that 0.08 mm. should be added to the scale reading. The reading in figure 1-1-70 B equals 38.00 mm. + 0.50 mm. + 0.08 mm. = 38.58 mm.

If a vernier caliper is calibrated in either English measure or in metric measure, usually one side will be calibrated to take outside measurements and the other to take inside measurements directly. The vernier plate for inside measurements is set to compensate for the thickness of the measuring points of the tools. But if a vernier caliper is calibrated for both English and metric measure, one of the scales will appear on one side and one on the other. Then it will be necessary, when taking inside measurements over the measuring points, to add certain amounts to allow for their thickness; for example, the following table shows the amounts to be added for various sizes of vernier calipers:

Measuring Point Allowances

Size of Caliper	English Measure	Metric Measure
6" or 150 mm.	Add 0.250"...	Add 6.35 mm.
12" or 300 mm.	.300"...	7.62 mm.
24" or 600 mm.	.300"...	7.62 mm.
36" or 900 mm.	.500"...	12.70 mm.

CARE OF THE VERNIER CALIPER

The inside faces of the jaws and the outside of the tips must be treated with great care. If they become worn, or the jaws bent, the tool will no longer give accurate readings. The accuracy of vernier calipers should be checked periodically by measuring an object of known dimension. Vernier calipers can be adjusted when they are not accurate, but the manufacturer's recommendations for this adjustment must be followed.

Keep vernier calipers lightly oiled to prevent rust and keep them stored away from heavy tools. A vernier caliper looks something like a monkey wrench, but never use it as such.

MICROMETER

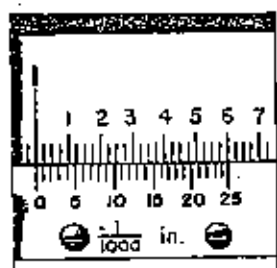
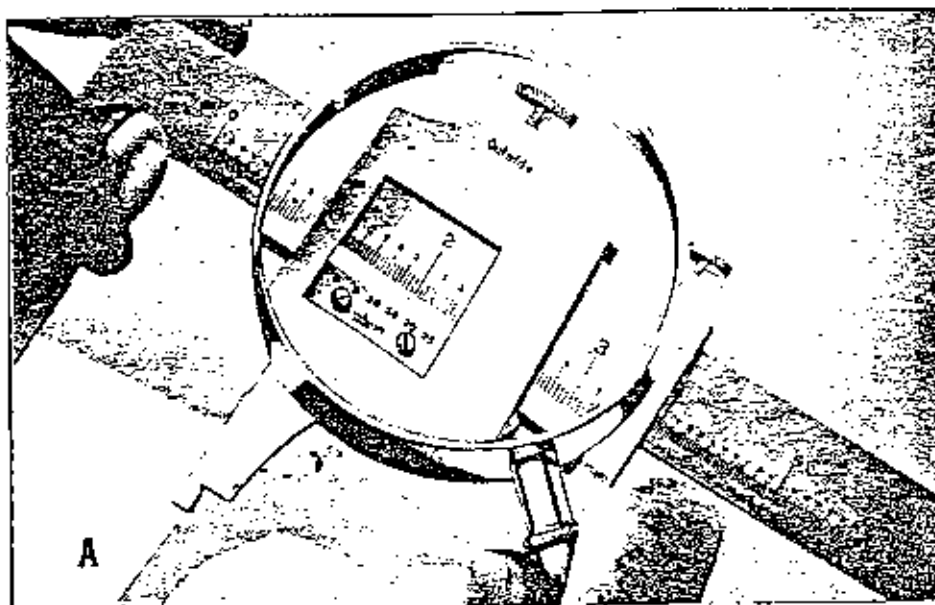
In much wider use than the vernier caliper is the micrometer commonly called the "mike." It is important that a person who is working with machinery or in a machine shop thoroughly understand the mechanical principles, construction, use, and care of the micrometer. Figure 1-1-71 shows an outside micrometer caliper with the various parts clearly indicated. Before attempting to use the tool, you should become familiar with the nomenclature, especially the frame, anvil, spindle, sleeve (barrel), and thimble. Micrometers are needed to measure distances to the nearest one thousandth of an inch. The measurement is usually expressed or written as a decimal; so you must know the method of writing and reading decimals.

TYPES OF MICROMETERS

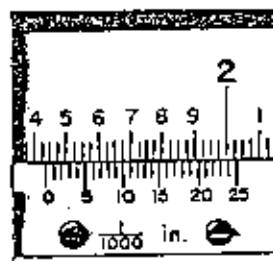
There are three types of micrometers that are most commonly used: the outside micrometer caliper (including the screw thread micrometer), the inside micrometer, and the depth micrometer. (See fig. 1-1-72.) The outside micrometer is used for measuring outside dimensions, such as the diameter of a piece of round stock. The screw thread micrometer is used to determine the pitch diameter of screws. The inside micrometer is used for measuring inside dimensions, as for example, the inside diameter of a tube or hole, the bore of a cylinder, or the width of a recess. The depth micrometer is used for measuring the depth of holes or recesses.

SELECTING THE PROPER MICROMETER

The types of micrometers commonly used are made so that the longest movement possible between the spindle and the anvil is 1 inch. This movement is called the "range." The frames of micrometers, however, are available in a wide variety of sizes, from 1 inch up to as large as 24 inches. The range of a 1-inch micrometer



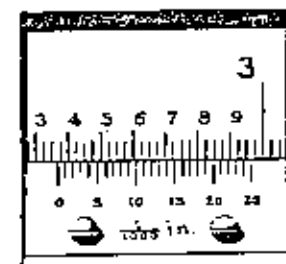
B



C



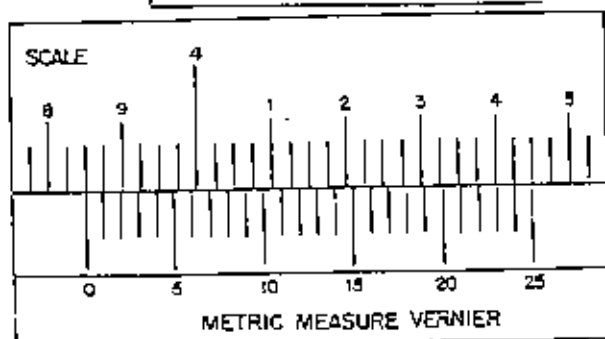
1



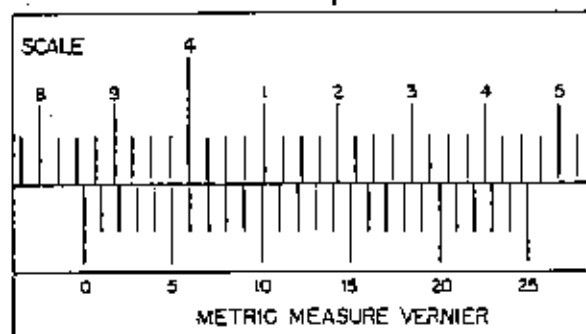
2

D

Figure 1-1-69.—Vernier caliper.



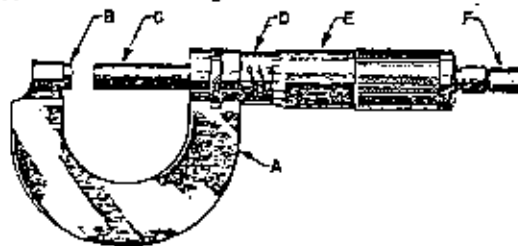
A



B

Figure 1-1-70.—Metric-measure vernier scales.

is from 0 to 1 inch; in other words, it can be used on work where the part to be measured is 1 inch or less. A 2-inch micrometer has a range from 1 inch to 2 inches, and will measure only work between 1 and 2 inches thick; a 6-inch micrometer has a range from 5 to 6 inches, and will measure only work between 5 and 6 inches thick. It is necessary, therefore, that the mechanic in selecting a micrometer first find the approximate size of the work to the nearest inch, and then select a micrometer that will fit it. For example, to find the exact diameter of a piece of round stock, use a rule and find the approximate diameter of the stock. If it is found to be approximately 3 1/4 inches, a micrometer with a 3- to 4-inch range would be required to measure the exact diameter. Similarly, with inside and depth micrometers, rods of suitable lengths must be fitted into the tool to get the approximate dimension within an inch, after which the exact measurement is read by turning the thimble. The size of a micrometer is given as the size of the largest work it will measure.



A. Frame
B. Anvil
C. Spindle
D. Sleeve
E. Thimble
F. Ratchet stop

Figure 1-1-71.—Nomenclature of an outside micrometer caliper.

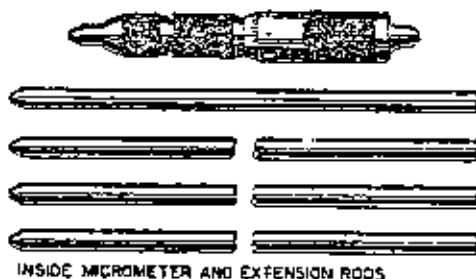
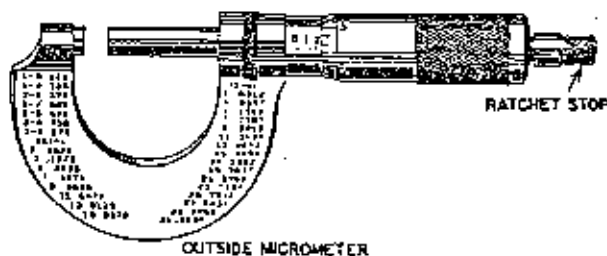


Figure 1-1-72.—Common types of micrometers.

READING A MICROMETER CALIPER

The spindle and the thimble of the micrometer caliper illustrated in figure 1-1-71, which shows the parts of a 1-inch micrometer caliper, are in one piece. The spindle is moved toward or away from the anvil by turning the thimble.

The sleeve and thimble scales of the micrometer caliper have been enlarged in figure 1-1-73. To understand these scales, you need to know that the threaded section on the spindle, which revolves, has 40 threads per inch. Therefore, every time the thimble completes a revolution, the spindle advances or recedes 1/40" (0.025").

Notice in figure 1-1-73 that the horizontal line on the sleeve is divided into 40 equal parts per inch. Every fourth graduation is numbered 1, 2, 3, 4, etc., representing 0.100", 0.200",

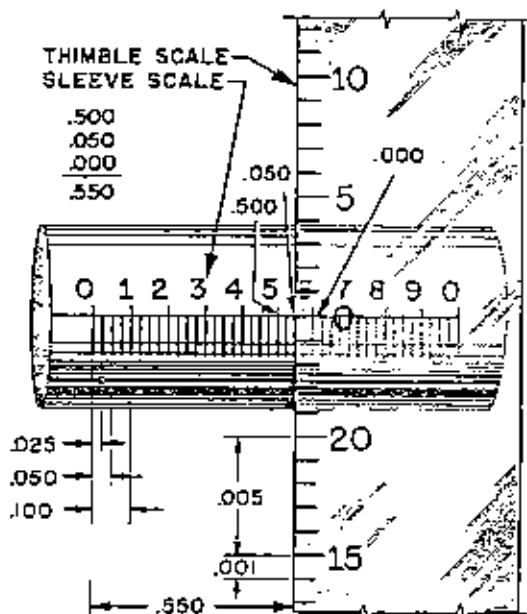
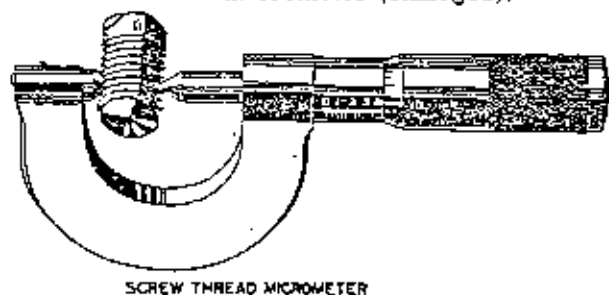


Figure 1-1-73.—Sleeve and thimble scales of a micrometer (enlarged).



DEPTH MICROMETER AND EXTENSION RODS

etc. When you turn the thimble so that its edge is over the first sleeve line past the "0" on the thimble scale, the spindle has opened 0.025". If you turn the spindle to the second mark, it has moved 0.025" plus 0.025" or 0.050". You use the scale on the thimble to complete your reading when the edge of the thimble stops between graduated lines. This scale is divided into 25 equal parts, each part representing 1/25 of a turn. And 1/25 of 0.025" is 0.001". As you can see, every fifth line on the thimble scale is marked, 5, 10, 15, etc. The thimble scale, therefore, permits you to take very accurate readings to the thousandths of an inch, and, since you can estimate between the divisions on the thimble scale, fairly accurate readings to the ten thousandth of an inch are possible.

The closeup in figure 1-1-74 will help you understand how to take a complete micrometer reading. Count the units on the thimble scale and add them to the reading on the sleeve scale. The reading in the figure shows a sleeve reading of 0.250" (the thimble having stopped slightly more than halfway between 2 and 3 on the sleeve) with the 10th line on the thimble scale coinciding with the horizontal sleeve line. Number 10 on this scale means that the spindle has moved away from the anvil an additional 10 X 0.001" or 0.010". Add this amount to the 0.250" sleeve reading, and the total distance is 0.260".

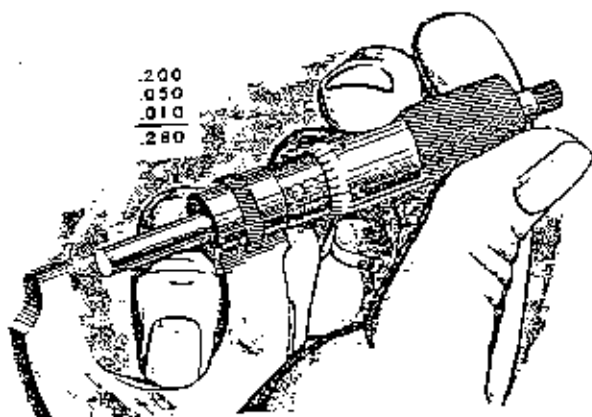


Figure 1-1-74.—Read a micrometer caliper.

Read each of the micrometer settings in figure 1-1-75 so that you can be sure of yourself when you begin to use this tool on the job.

The correct readings are given following the figure so that you can check yourself.

Figure 1-1-76 shows a reading in which the horizontal line falls between two graduations on the thimble scale and is closer to the 15 graduation than it is to the 14. To read this to THREE decimal places, refer to figure 1-1-76 A. To read it to FOUR decimal places, estimate the number of tenths of the distance between thimble-scale graduations the horizontal line

has fallen. Each tenth of this distance equals one ten-thousandth (0.0001) of an inch. Add the ten-thousandths to the reading as shown in figure 1-1-76 B.

Reading a Vernier Micrometer Caliper

Many times you will be required to work to exceptionally precise dimensions. Under these conditions it is better to use a ten-thousandth micrometer. This instrument has a third scale which is a vernier scale, shown in figure 1-1-77, that furnishes the fine readings between the lines on the thimble rather than making you estimate. The 10 spaces on the vernier are equivalent to 9 spaces on the thimble. Therefore, each unit on the vernier scale is equal to 0.0009" and the difference between the sizes of the units on each scale is 0.0001".

When a line on the thimble scale does not coincide with the horizontal sleeve line, you can determine the additional space beyond the readable thimble mark by finding which vernier mark coincides with a line on the thimble scale. Add this number, as that many ten-thousandths of an inch, to the original reading. In figure 1-1-78 see how the second line on the vernier scale coincides with a line on the thimble scale.

This means that the 0.011 mark on the thimble scale has been advanced an additional 0.0002" beyond the horizontal sleeve line. When you add this to the other readings, the reading will be 0.200 + 0.075 + 0.011 + 0.0002 or 0.2862", as shown.

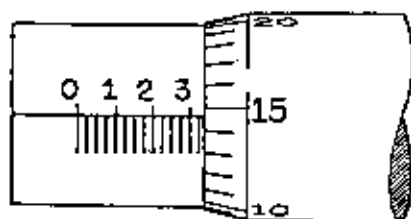
CARE OF MICROMETERS

Keep micrometers clean and lightly oiled. Make sure they are placed in a case or box when they are not in use. Anvil faces must be protected from damage and must not be cleaned with emery cloth or other abrasive.

If a 1 inch micrometer caliper does not read zero when the spindle touches the anvil, and both are clean at the point of contact, the zero setting should be corrected. This will eliminate the necessity of adding or subtracting a "zero correction" numerically to each reading as would otherwise be necessary if this adjustment were not made.

The zero setting on all micrometers is not made in exactly the same way. Refer to either the instructions that come with the micrometer or to the manufacturer's catalog for specific directions for a particular tool.

Master test gages are sometimes supplied for checking the accuracy of the micrometer. If these are not available, gage blocks can be used for this purpose. To adjust a micrometer larger than a 1-inch size, a master test gage or gage block must be used between the anvil and spindle to test for the correct zero reading.



$$A \begin{cases} .300 \\ .025 \\ .015 \\ \hline .340 \end{cases} \quad B \begin{cases} .300 \\ .025 \\ .014 \\ .0007 \\ \hline .3397 \end{cases}$$

Figure 1-1-76.

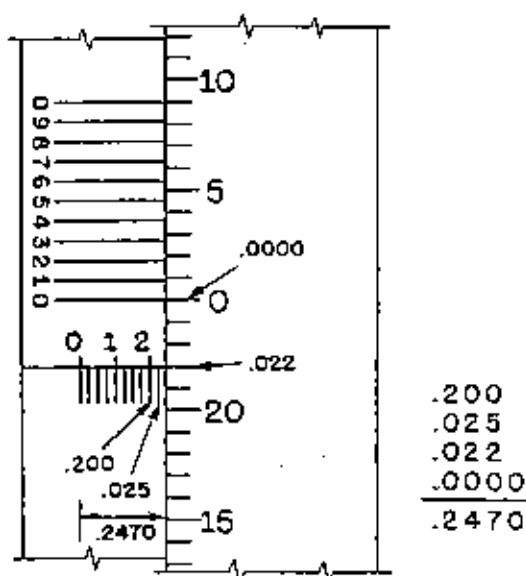


Figure 1-1-77.—Vernier scale on a micrometer.

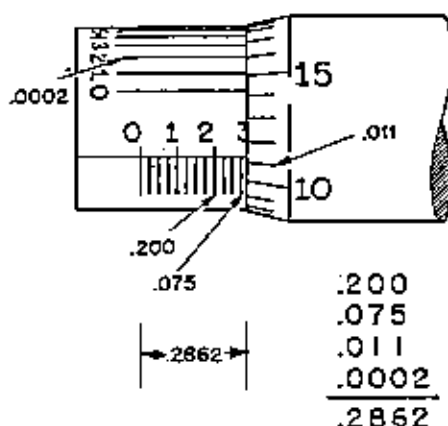


Figure 1-1-78.—Read a vernier micrometer caliper.

SQUARES

Squares are primarily used for testing and checking trueness of an angle or for laying out lines on materials before cutting. Most squares have a rule marked on their edge and may also be used for measuring. There are several types of squares commonly used by personnel working with wood and metal.

CARPENTER'S SQUARE

The size of a carpenter's steel square is usually 12 inches x 8 inches, 24 inches x 16 inches, or 24 inches x 18 inches. The 12- or 24-inch side is called the blade and the 8-, 16-, or 18-inch side, which is at right angles to the blade, is called the tongue. (See fig. 1-1-78.) The flat sides of the blade and the tongue are graduated in inches and fractions of an inch. Both the blade and the tongue may be used as a rule and also as a straightedge in layout operations. Besides the inch and fractional graduations on the square, several tables (fig. 1-1-79) are marked on it.

The carpenter's square enables you, when working with wood, to lay out guidelines for cutting rafters, oblique joints, stairs, and so forth. You can perform many calculations with the aid of the tables and graduations marked on the blade and tongue of the square. The most common uses for this square are laying out and squaring up large stock and large patterns, and for testing the flatness and squareness of large surfaces by placing the square at right angles to adjacent surfaces and observing if light shows between the work and the square.

TRY SQUARE

The try square (fig. 1-1-80) consists of two parts at right angles to each other; a thick wood or iron stock and a thin, steel blade. Most try squares are made with the blades graduated in inches and fractions of an inch. The blade length varies from 2 inches to 12 inches. This square is used for setting or checking lines or surfaces which have to be at right angles to each other. The carpenter's square can be used for the same purpose, but is often too large to use accurately.

SLIDING T BEVEL

The sliding T-bevel (fig. 1-1-81) is an adjustable try square with a slotted beveled blade. Blades are normally 6 or 8 inches long. The sliding T-bevel is used for laying out angles other than right angles, and for testing constructed angles such as bevels. These squares are made with either wood or metal handles.

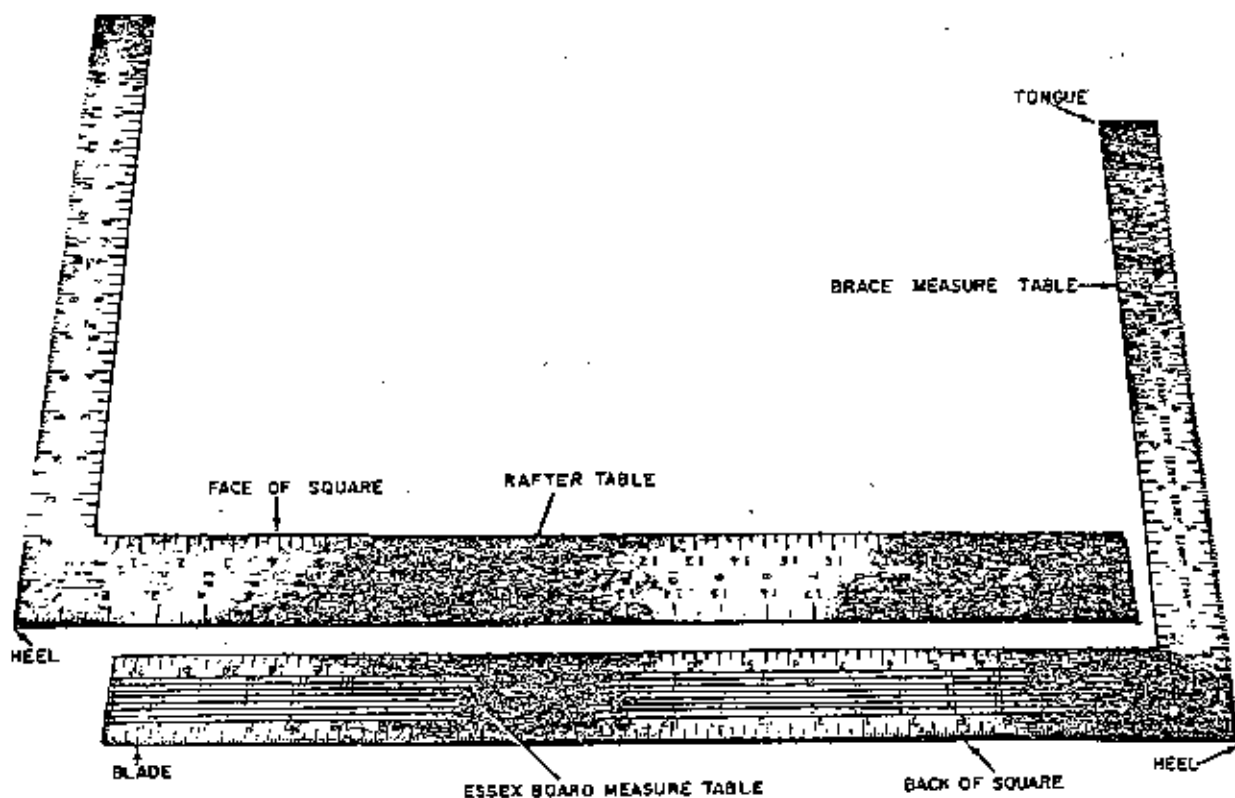


Figure 1-1-79.—Carpenters square.

COMBINATION SQUARE

A combination square that is equipped with a **SQUARE HEAD**, **PROTRACTOR HEAD**, and a **CENTER HEAD** is the most versatile layout tool that is used by personnel. As its name implies, it combines the functions of several tools, and serves a wide variety of purposes. It consists of a hardened steel scale and the movable heads. (See fig. 1-1-82.)

The **SQUARE HEAD** may be adjusted to any position along the scale and clamped securely, or may be removed entirely. It can thus serve as a depth gage, height gage, or scribing gage. Two of the faces of the head are ground at right angles to each other, and a third face at 45 degrees. A small spirit level is built into the head for checking whether surfaces are plumb, and a small scriber is housed in a hole in the end of the head for marking layout lines.

The **CENTER HEAD** can be slid on to the blade in place of the stock head. This is a V-shaped member so designed that the center of the 90 degree V will lie exactly along one edge of the blade. This attachment is useful when locating the exact center of round stock.

The **PROTRACTOR HEAD**, commonly called a bevel protractor, can be attached to the scale, adjusted to any position on it, and turned and locked at any desired angle. Some types have a shoulder on only one side of the blade, others have it extending on both sides. Angular graduations usually read from 0 to 180 degrees both

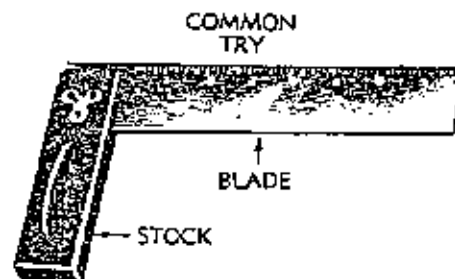


Figure 1-1-80.—Common try square.

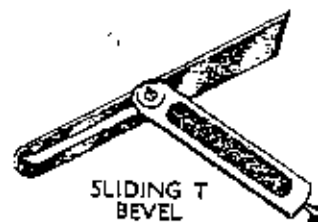


Figure 1-1-81.—Sliding T-bevel.

ways, permitting the supplement of the angle to be read. A spirit level may be included on some models forming, in effect, an adjustable level to show any required degree.

CARE OF SQUARES

Make certain the blades, heads, dials, and all accessories are clean. Apply a light coat of oil on all metal surfaces to prevent rusting when not in use. Do not use squares for purposes other than those intended. When storing squares or bevels for long periods of time, apply a liberal amount of oil or rust-preventive compound to all surfaces, wrap in oiled paper or cloth, and place in containers or on racks away from other tools.

MISCELLANEOUS MEASURING GAGES

There are a number of miscellaneous tools that are called gages and may be used for measuring or testing and setting distances. Some of the gages that will be discussed here will also be useful for layout work as well as for measuring.

DEPTH GAGE

A depth gage is an instrument for measuring the depth of holes, slots, counterbores, recesses, and the distance from a surface to some recessed part. The RULE DEPTH GAGE and the MICROMETER DEPTH GAGE are the most commonly used. (See fig. 1-1-83.)

The rule depth gage is a graduated rule with a sliding head designed to bridge a hole or slot, and to hold the rule perpendicular to the surface on which the measurement is taken. This type has a measuring range of 0 to 5 inches. The sliding head has a clamping screw so that it may be clamped in any position. The sliding head has a flat base which is perpendicular to the axis of the rule and ranges in size from 2 to 2 5/8 inches in width and from 1/8 to 1/4 inch in thickness.

The micrometer depth gage consists of a flat base attached to the barrel (sleeve) of a micrometer head. These gages have a range from 0 to 9 inches, depending on the length of extension rod used. The hollow micrometer screw (the threads on which the thimble rotates) itself has a range of either 1/2 or 1 inch. Some are provided with a ratchet stop. The flat base ranges in size from 2 to 6 inches. Several extension rods are normally supplied with this type of gage.

SURFACE GAGE

A surface gage is a measuring tool generally used to transfer measurements to work by scribing a line, and to indicate the accuracy or parallelism of surfaces.

The surface gage (fig. 1-1-84) consists of a base with an adjustable spindle to which may be clamped a scribe or an indicator. Surface gages are made in several sizes and are classified by the length of the spindle, the smallest spindle being 4 inches long, the average 9 or 12 inches long and the largest 18 inches. The scribe is fastened to the spindle with a clamp. The bottom and the front end of the base of the

surface gage have deep V-grooves cut in them, which allow the gage to measure from a cylindrical surface.

The spindle of a surface gage may be adjusted to any position with respect to the base and tightened in place with the spindle nut. The rocker adjusting screw provides for the finer adjustment of the spindle by pivoting the spindle rocker bracket. The scribe can be positioned at any height and in any desired direction on the spindle by tightening the scribe nut. The scribe may also be mounted directly in the spindle nut mounting, in place of the spindle, and used where the working space is limited and the height of the work is within range of the scribe.

SURFACE PLATE

A surface plate provides a true, smooth, plane surface. It is a flat-topped steel or cast iron plate that is heavily ribbed and reinforced on the under side. (See fig. 1-1-85.) It is often used in conjunction with a surface gage as a level base on which the gage and part to be measured are placed to obtain accurate measurements.

The surface plate can also be used for testing parts that must have flat surfaces. Before using the plate for testing smear a thin film of Prussian blue, or some other color pigment, on its surface; then rub the flat surface to be tested over the plate and the color pigment will stick to the high spots.

The surface plate should be covered when not in use to prevent scratching, nicking, and denting. It must be handled carefully to prevent warping (twisting). Never use the surface plate as an anvil or workbench—except for precision layout work (marking and measuring).

THICKNESS (FEELER) GAGE

Thickness (feeler) gages are fixed in leaf form, to permit the checking and measuring of small openings such as contact points, narrow slots, and so forth. They are widely used to check the flatness of parts in straightening and grinding operations and in squaring objects with a try square.

Thickness gages are made in many shapes and sizes; usually 2 to 26 blades are grouped into one tool and graduated in thousandths of an inch. (See fig. 1-1-86.) Most thickness gage blades are straight, while others are bent at the end at 45 and 90 degree angles. Some thickness gages are grouped so that there are several short and several long blades together. Thickness gages are also available in single blades and in strip form for specific measurements. For convenience, groups of thickness blades are equipped with a locking screw in the case that locks the blade to be used in the extended position.

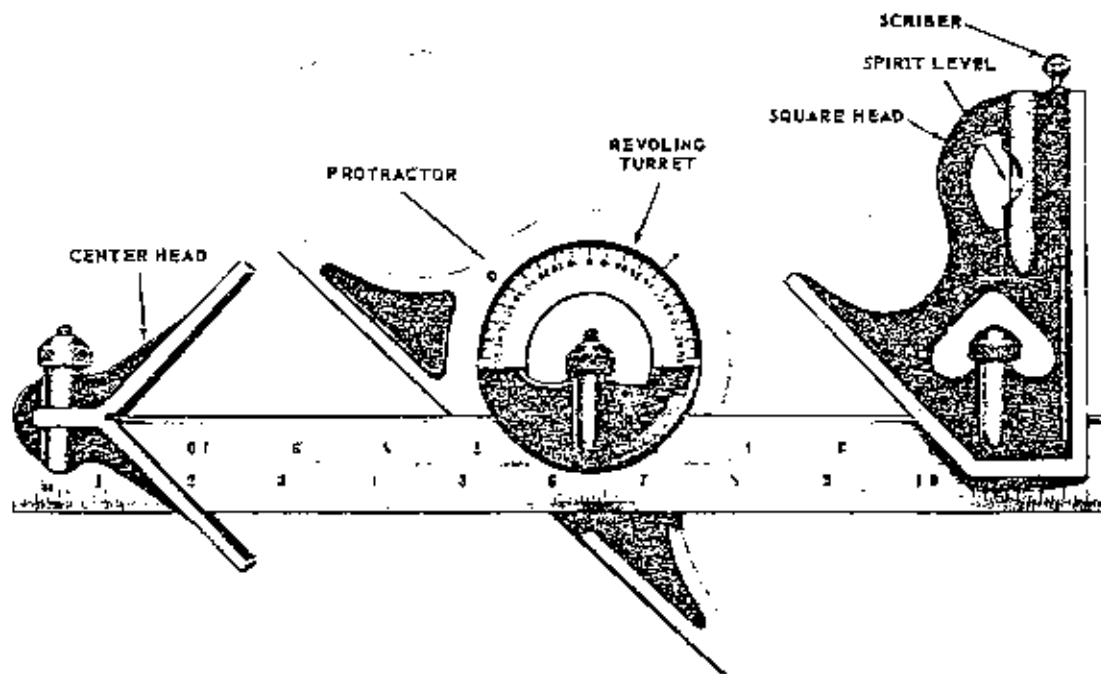


Figure 1-1-82.—Combination square set.

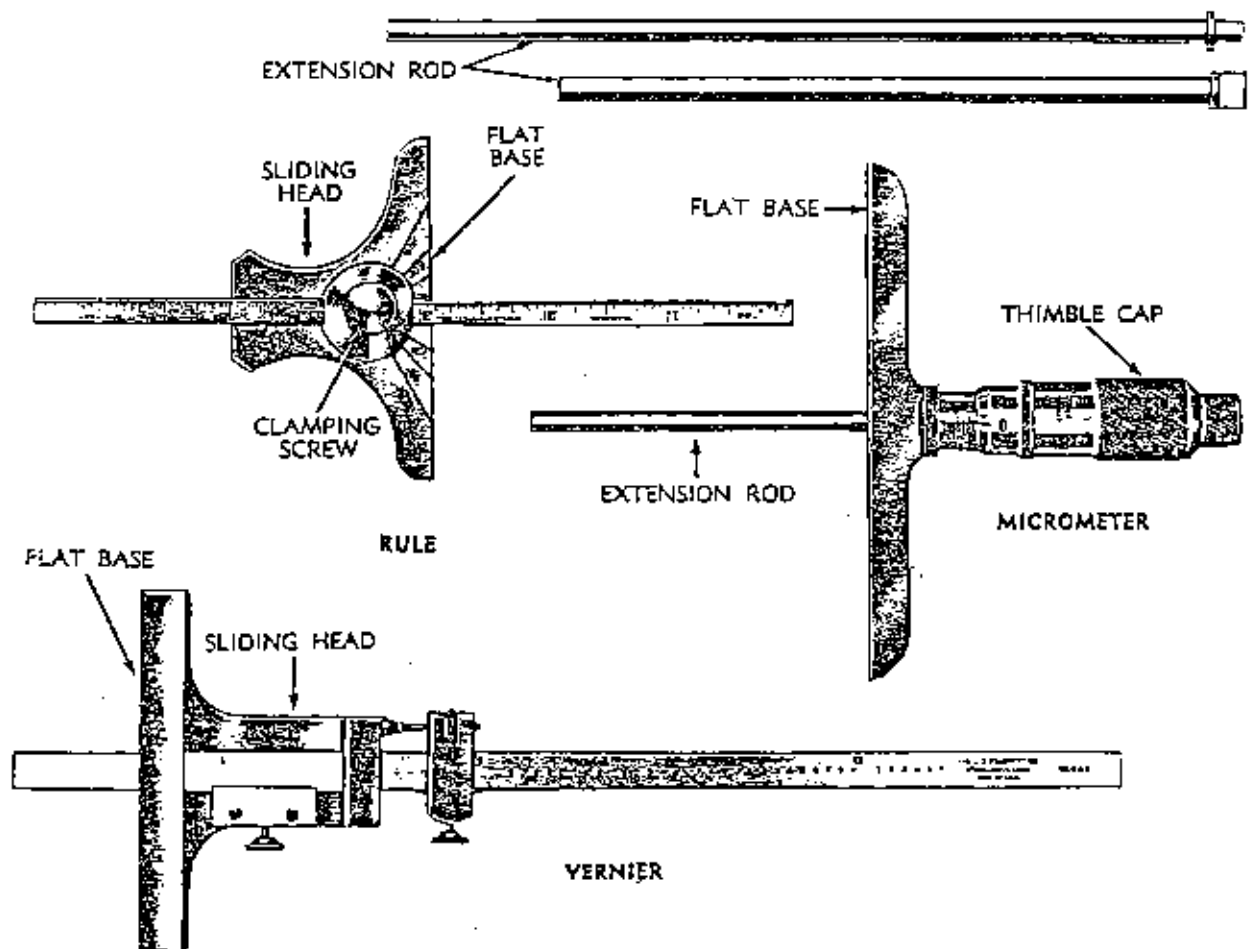


Figure 1-1-83.—Types of depth gages.

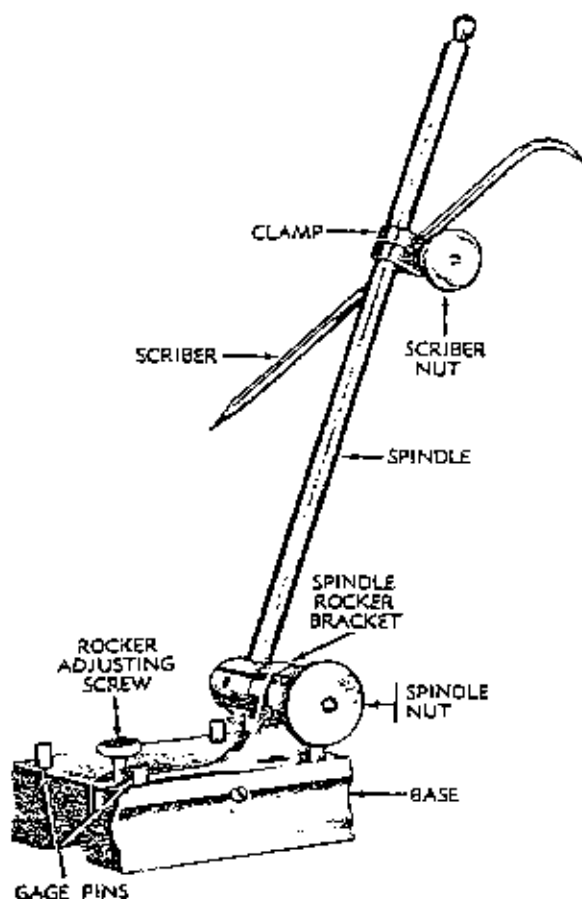


Figure 1-1-84.—Surface gage.



Figure 1-1-85.—Surface plate.

THREAD GAGE

Thread gages (screw-pitch gages) are used to determine the pitch and the number of threads per inch. (See fig. 1-1-87.) They consist of thin leaves whose edges are toothed to correspond to standard thread sections.

To measure the pitch of a thread, compare it with the standards of the gage, holding a gage leaf to the thread being gaged until you find an exact fit. If possible, look at the fit toward a source of light, since a difference of one thread arm. The tool may then be withdrawn and the distance across the arms measured.

These tools are commonly furnished in sets, the smallest gage for measuring distances from $5/16$ to $1/2$ inch, and the largest for distances from $3 1/2$ to 6 inches.

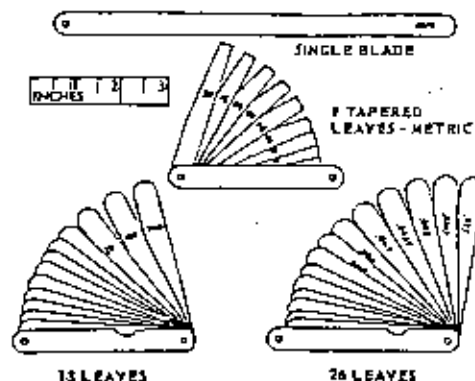


Figure 1-1-86.—Thickness (Feeler) gages.

per inch, in the finer threads, is not easily detected.

The number of threads per inch is indicated by the numerical value on the blade which is found to fit the threads. Using this value as a basis, correct sizes of nuts, bolts, tap cutters, and die cutters are selected for use on the threads.

If the number of threads per inch on a nut equal the number of threads per inch on a bolt, the nut can be successfully applied without danger of stripping the threads on either.

WIRE GAGE

The wire gage (fig. 1-1-88) is used for gaging metal wire, and a similar gage is used to check the size of hot and cold rolled steel, sheet and plate iron, and music wire. The wire gage is circular in shape with cutouts in the outer perimeter. Each cutout gages a different size wire from 0 to 36 of the English Standard Wire Gage. A different gage is used for American Standard wire, and still another for U.S. Standard sheet and plate iron and steel.

TELESCOPING GAGE

Telescoping gages are used for measuring the inside size of slots or holes up to 6 inches in width or diameter. They are T-shaped tools in which the shaft of the T is used as a handle, and the crossarm used for measuring. (See fig. 1-1-89.) The crossarms telescope into each other and are held out by a light spring. To use the gage the arms are compressed, placed in the hole to be measured, and allowed to expand. A twist of the locknut on top of the handle locks the arms. The tool may then be withdrawn and the distance across the arms measured.

SMALL HOLE GAGE

For measuring smaller slots or holes than the telescoping gages will measure, small hole gages can be used. These gages come in sets of four or more and will measure distances of approximately $1/8$ to $1/2$ inch.

The small hole gage (fig. 1-1-89) consists of a small, split, ball-shaped member mounted on

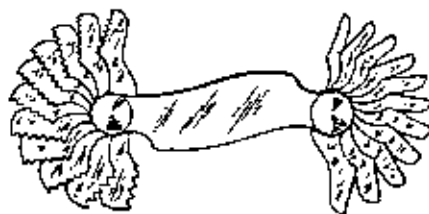


Figure 1-1-87.—Screw pitch gage.

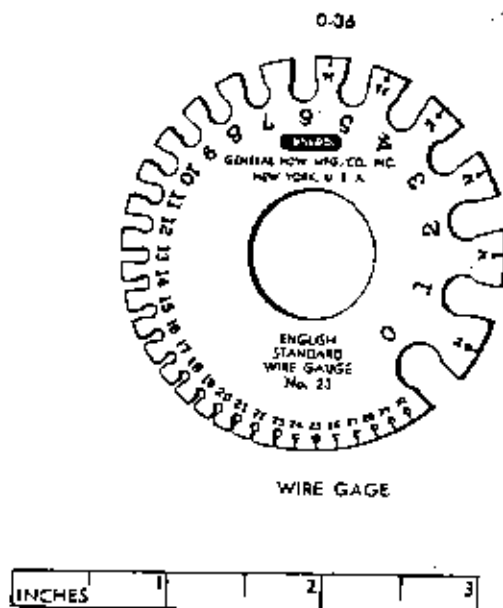


Figure 1-1-88.—English standard wire gage.

the end of a handle. The ball is expanded by turning a knurled knob on the handle until the proper feel is obtained, and then the size of the ball-shaped member on the end of the gage can be measured with an outside micrometer caliper. On some types of small hole gages, the ball is flattened at the bottom near the centerline to permit use in shallow holes and recesses.

MARKING GAGES

A marking gage is used to mark off guide-lines parallel to an edge, end, or surface of a piece of wood or metal. It has a sharp spur or pin that does the marking.

Marking gages (fig. 1-1-90) are made of wood or steel. They consist of a graduated beam about 8 inches long on which a head slides. The head can be fastened at any point on the beam by means of a thumbscrew. The thumbscrew presses a brass shoe tightly against the beam and locks it firmly in position. The steel pin or spur that does the marking projects from the beam about 1/16 inch.

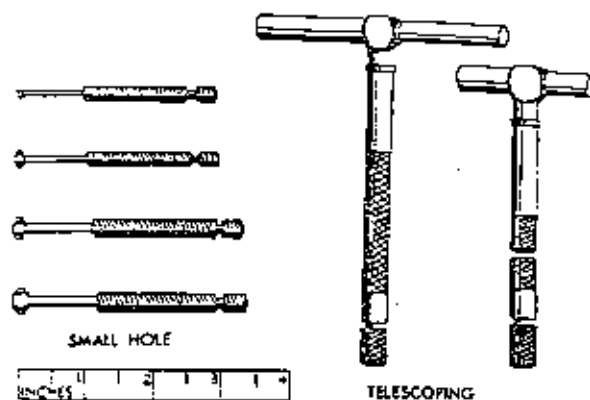


Figure 1-1-89.—Small hole and telescoping

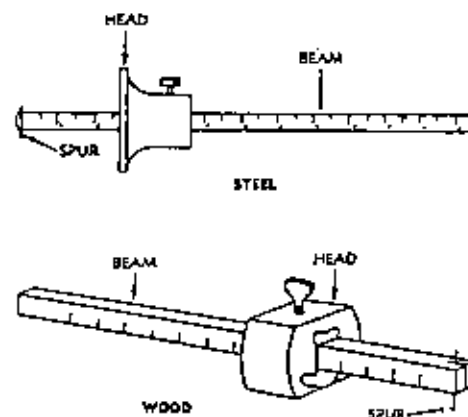


Figure 1-1-90.—Marking gages.

TAPS AND DIES

Taps and dies are used to cut threads in metal, plastics, or hard rubber. The taps are used for cutting internal threads, and the dies are used to cut external threads. There are many different types of taps. However, the most common are the taper, plug, bottoming, and pipe taps. (See fig. 1-1-91.)

The taper (starting) hand tap has a chamfer length of 8 to 10 threads. These taps are used when starting a tapping operation and when tapping through holes.

Plug hand taps have a chamfer length of 3 to 5 threads and are designed for use after the taper tap.

Bottoming hand taps are used for threading the bottom of a blind hole. They have a very short chamfer length of only 1 to 1 1/2 threads for this purpose. This tap is always used after the plug tap has already been used. Both the taper and plug taps should precede the use of the bottoming hand tap.

Pipe taps are used for pipe fittings and other places where extremely tight fits are necessary. The tap diameter, from end to end of threaded portion, increases at the rate of 3/4 inch per foot. All the threads on this tap do the cutting, as compared to the straight taps where only the nonchamfered portion does the cutting.

Dies are made in several different shapes and are of the solid or adjustable type. The square pipe die (fig. 1-1-92) will cut American Standard Pipe Thread only. It comes in a variety of sizes for cutting threads on pipe with diameters of 1/8 inch to 3 inches.

A rethreading die (fig. 1-1-92) is used principally for dressing over bruised or rusty threads on screws or bolts. It is available in a variety of sizes for rethreading American Standard Coarse and Fine threads. These dies are usually hexagon in shape and can be turned with a socket, box, open-end, or any wrench that will fit. Rethreading dies are available in sets of 6, 10, 14, and 28 assorted sizes in a case.

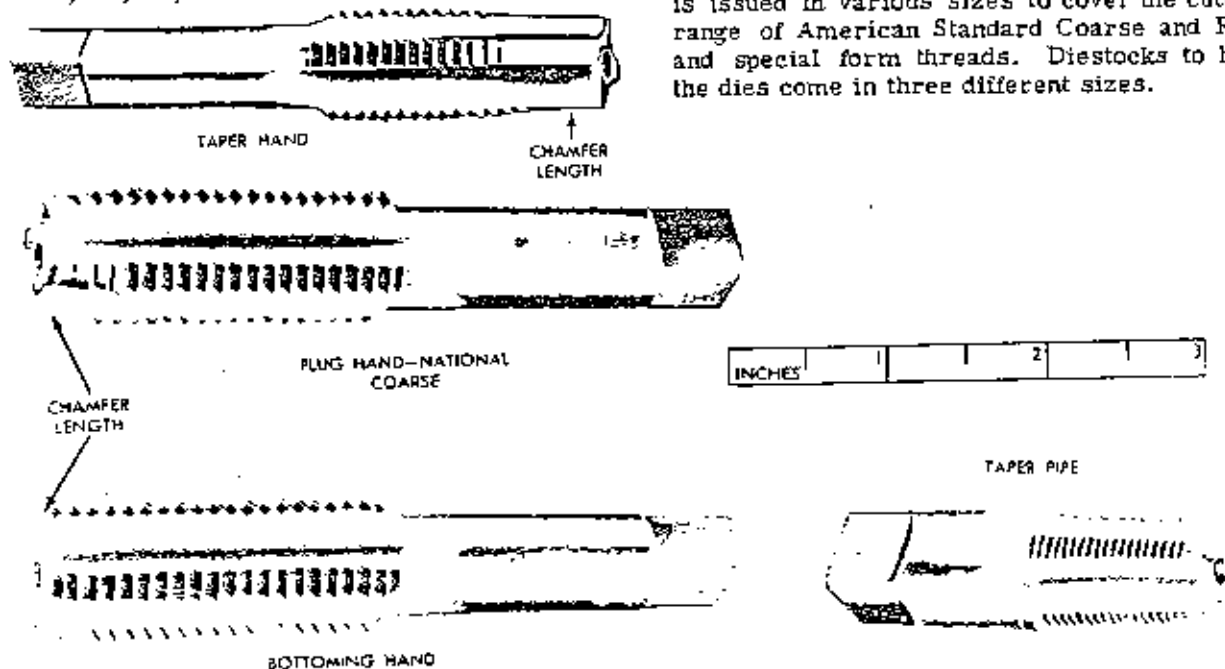


Figure 1-1-91.—Types of common taps.

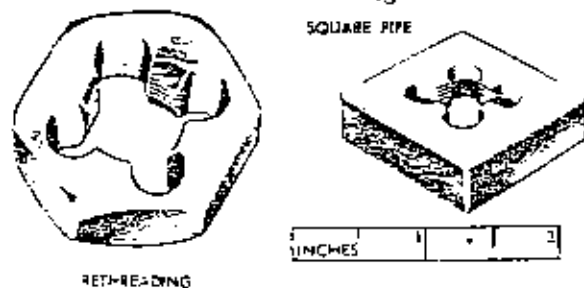


Figure 1-1-92.—Types of solid dies.

Round split adjustable dies (fig. 1-1-93) are called "Button" dies and can be used in either hand diestocks or machine holders. The adjustment in the screw adjusting type is made by a

fine-pitch screw which forces the sides of the die apart or allows them to spring together. The adjustment in the open adjusting types is made by means of three screws in the holder, one for expanding and two for compressing the dies. Round split adjustable dies are available in a variety of sizes to cut American Standard Coarse and Fine threads, special form threads, and the standard sizes of threads that are used in Britain and other European countries. For hand threading, these dies are held in diestocks (fig. 1-1-94). One type die stock has three pointed screws that will hold round dies of any construction, although it is made specifically for open adjusting-type dies.

Two piece collet dies (fig. 1-1-93) are used with a collet cap (fig. 1-1-94) and collet guide. The die halves are placed in the cap slot and are held in place by the guide which screws into the underside of the cap. The die is adjusted by means of setscrews at both ends of the internal slot. This type of adjustable die is issued in various sizes to cover the cutting range of American Standard Coarse and Fine and special form threads. Diestocks to hold the dies come in three different sizes.

Two-piece rectangular pipe dies (fig. 1-1-93) are available to cut American Standard Pipe threads. They are held in ordinary or ratchet-type diestocks. (See fig. 1-1-95.) The jaws of the dies are adjusted by means of setscrews. An adjustable guide serves to keep the pipe in alignment with respect to the dies. The smooth jaws of the guide are adjusted by means of a cam plate; a thumbscrew locks the jaws firmly in the desired position.

Threading sets are available in many different combinations of taps and dies, together with diestocks, tap wrenches, guides and necessary screwdrivers and wrenches to loosen and tighten adjusting screws and bolts. Figure 1-1-96 illustrates typical threading set for pipe, bolts, and screws.

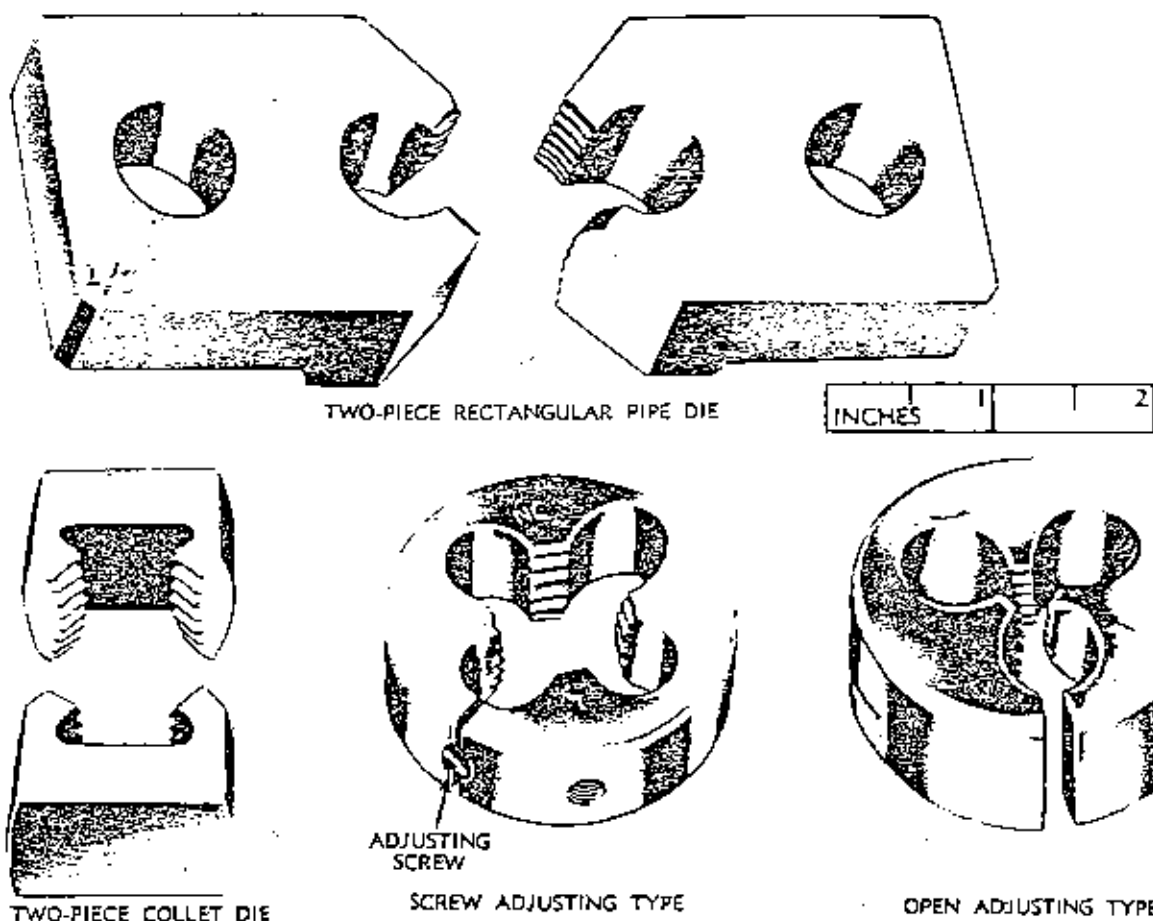


Figure 1-1-93.—Types of adjustable dies.

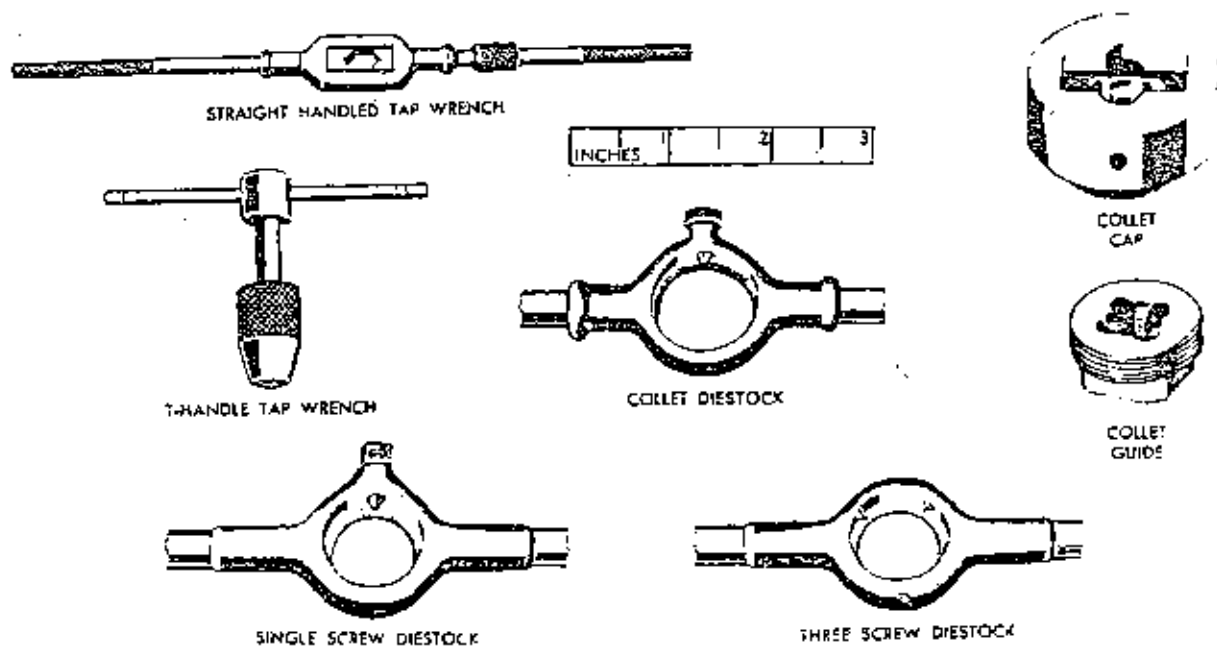


Figure 1-1-94.—Diestocks, diecollet, and tap wrenches.

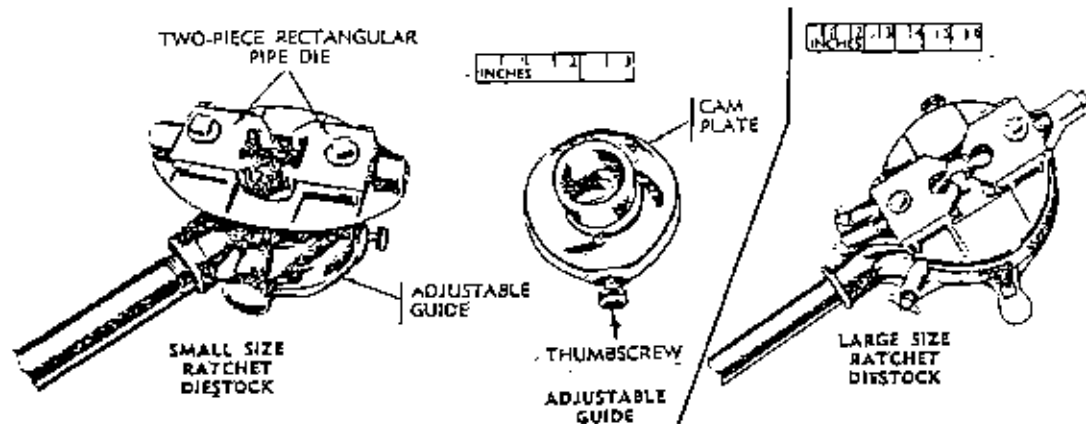
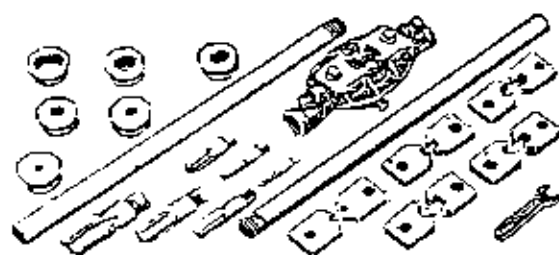


Figure 1-1-95.—Adjustable die guide and ratchet diestocks.



PIPE THREADING SET WITH RECTANGULAR ADJUSTABLE DIES, DIESTOCK, WRENCH, GUIDES AND TAPS



BOLT AND SCREW THREADING SET WITH ROUND ADJUSTABLE SPLIT DIES, DIESTOCKS, TAPS, TAP WRENCHES, AND SCREWDRIVERS

Figure 1-1-96.—A typical threading set.

Never attempt to sharpen taps or dies. Sharpening of taps and dies involves several highly precise cutting processes which involve the thread characteristics and chamfer. These sharpening procedures must be done by experienced personnel in order to maintain the accuracy and the cutting effectiveness of taps and dies.

Keep taps and dies clean and well oiled when not in use. Store them so that they do not con-

tact each other or other tools. For long periods of storage, coat taps and dies with a rust-preventive compound, place in individual or standard threading set boxes, and store in a dry place.

THREAD CHASERS

Thread chasers are threading tools that have several teeth and are used to rethread damaged external or internal threads (chasing). (See fig. 1-1-97.) These tools are available to chase standard threads. The internal thread chaser has its cutting teeth located on a side face. The external thread chaser has its cutting teeth on the end of the shaft. The handle end of the tool shaft tapers to a point.

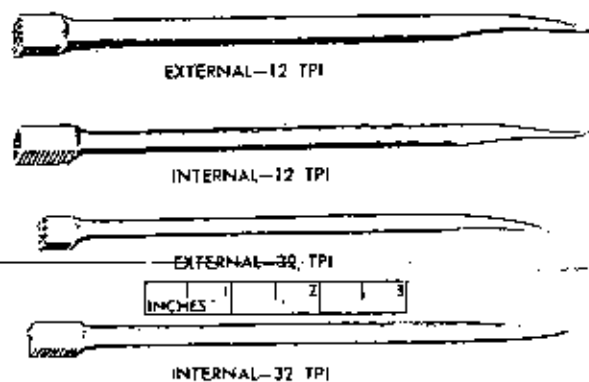


Figure 1-1-97.—Thread chasers.

SCREW AND TAP EXTRACTOR

Screw extractors are used to remove broken screws without damaging the surrounding material or the threaded hole. Tap extractors are used to remove broken taps.

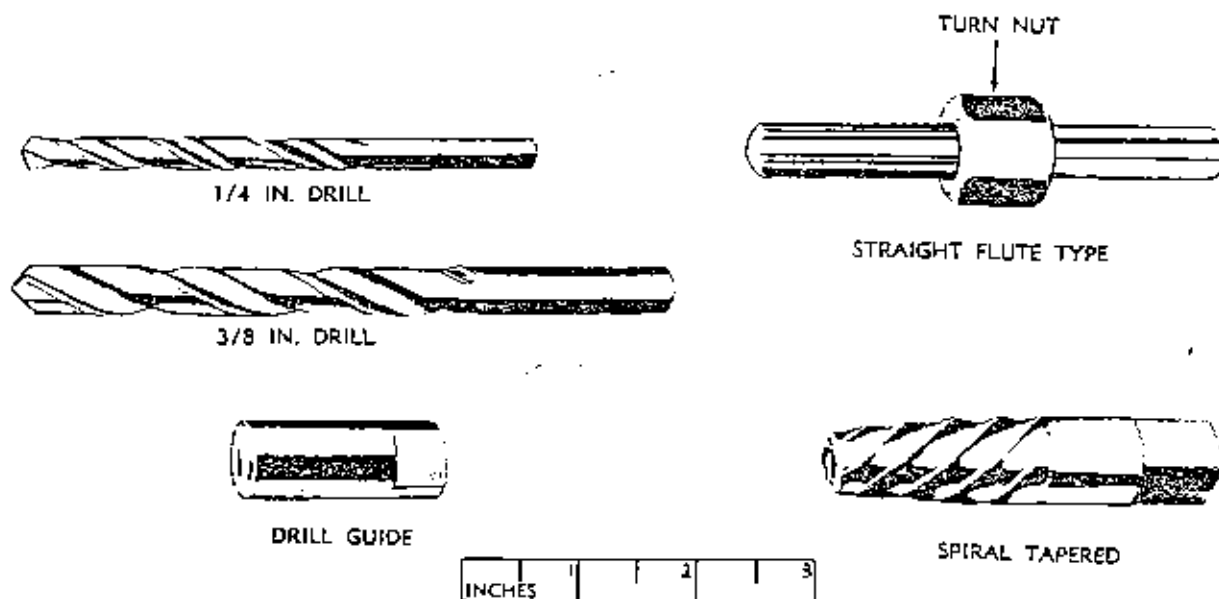


Figure 1-1-98.—Screw and tap extractors.

Some screw extractors (fig. 1-1-98) are straight, having flutes from end to end. These extractors are available in sizes to remove broken screws having 1/4 to 1/2 inch outside diameters. Spiral tapered extractors are sized to remove screws and bolts from 3/16 inch to 2 1/8 inches outside diameter.

Most sets of extractors include twist drills and a drill guide. Tap extractors are similar to the screw extractors and are sized to remove taps ranging from 3/16 to 2 1/8 inches outside diameter.

VICES AND CLAMPS

Vises are used for holding work when it is being planed, sawed, drilled, shaped, sharpened, or riveted, or when wood is being glued. Clamps are used for holding work which because of its shape and size cannot be satisfactorily held in a vise, or when a vise is not available. Clamps are generally used for light work.

Figure 1-1-99 shows the most common bench vises.

A MACHINIST'S BENCH VISE is a large steel vise with rough jaws that prevent the work from slipping. Most of these vises have a swivel base with jaws that can be rotated, while others cannot be rotated. A similar light duty model is equipped with a cutoff. These vises are usually bolt-mounted onto a bench.

THE BENCH AND PIPE VISE has integral pipe jaws for holding pipe from 3/4 inch to 3 inches in diameter. The maximum working main jaw opening is usually 5 inches, with a jaw width of 4 to 5 inches. The base can be swiveled to any position and locked. These vises are equipped with an anvil and are also bolted onto a workbench.

The CLAMP BASE VISE usually has a smaller holding capacity than the machinist's or the bench and pipe vise and is usually clamped to

the edge of a bench with a thumbscrew. These type vises can be obtained with a maximum holding capacity varying between 1 1/2 in. and 3 in. These vises normally do not have pipe holding jaws.

THE BLACKSMITH'S VISE (fig. 1-1-100) is used for holding work that must be pounded with a heavy hammer. It is fastened to a sturdy workbench or wall, and the long leg is secured into a solid base on the floor.

THE PIPE VISE (fig. 1-1-100) is specifically designed to hold round stock or pipe. The vise shown has a capacity of 1 to 3 inches. One jaw is hinged so that the work can be positioned and then the jaw brought down and locked. This vise is also used on a bench. Some pipe vises are designed to use a section of chain to hold down the work. Chain pipe vises range in size from 1/8- to 2 1/2 inch pipe capacity up to 1/2- to 8-inch pipe capacity.

A C-CLAMP (fig. 1-1-101) is shaped like the letter C. It consists of a steel frame threaded to receive an operating screw with a swivel head. It is made for light, medium, and heavy service in a variety of sizes.

A HAND SCREW CLAMP (fig. 1-1-101) consists of two hard maple jaws connected with two operating screws. Each jaw has two metal inserts into which the screws are threaded. The hand screw clamp is also issued from supply in a variety of sizes.

CARE OF VICES AND CLAMPS

Keep vises clean at all times. They should be cleaned and wiped with light oil after using. Never strike a vise with a heavy object and never hold large work in a small vise, since these practices will cause the jaws to become sprung or otherwise damage the vise. Keep jaws in good condition and oil the screws and the slide fre-

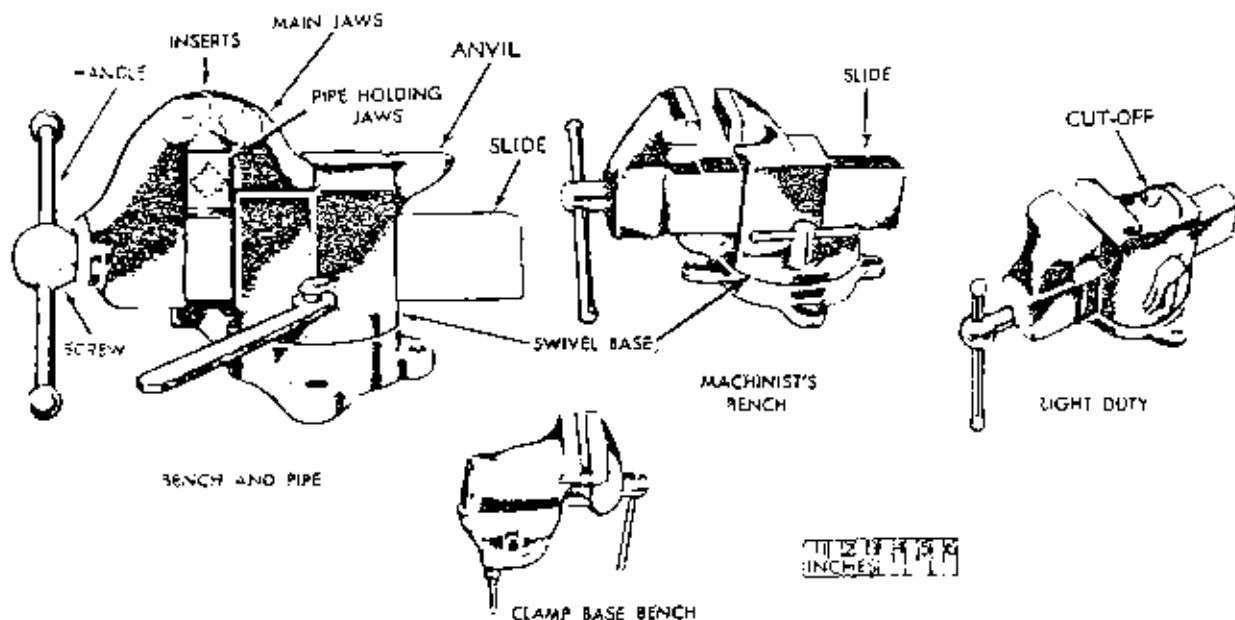


Figure 1-1-99.—Common types of bench vises.

quently. Never oil the swivel base of swivel jaw joint; its holding power will be impaired. When the vise is not in use, bring the jaws lightly together or leave a very small gap and leave the handle in a vertical position.

Threads of C-clamps must be clean and free from rust. The swivel head must also be clean, smooth, and grit free. If the swivel head becomes damaged, replace it as follows: pry open the crimped portion of the head and remove the head from the ball end of the screw (fig. 1-1-102). Replace with a new head and crimp. For short storage, wipe down the clamps with a light coat of engine oil and then hang them on racks or pins, or carefully place them in a toolbox. For long storage, apply a rust-preventive compound to the C-clamp.

The screw of hand screw clamps may break or become damaged, the inserts may become worn, or the wooden jaws may split or warp. When it is necessary to replace any of these parts, disassemble the clamp (fig. 1-1-103). Remove handles from screws by filing off peened end of attaching pins. Drive out pins. Turn both screws from the inserts and remove the inserts from the jaws. Replace damaged screws, inserts and handles. Install inserts in jaws and turn the screws into position in the two jaws. Turn new screws into handle or old screw into new handle, depending on which part is being replaced. Align holes and tap in a new pin. Peen end of pin to secure handle on screws. Keep screws lubricated with a few drops of light oil. Apply a light coat of linseed oil to wood surfaces to prevent them from drying out. If the finish of wooden jaws is worn and bare wood is exposed, coat jaws with varnish. Hang clamps on racks or pins, or carefully place them in a toolbox, to prevent damage when not in use. Wipe clean before storing.

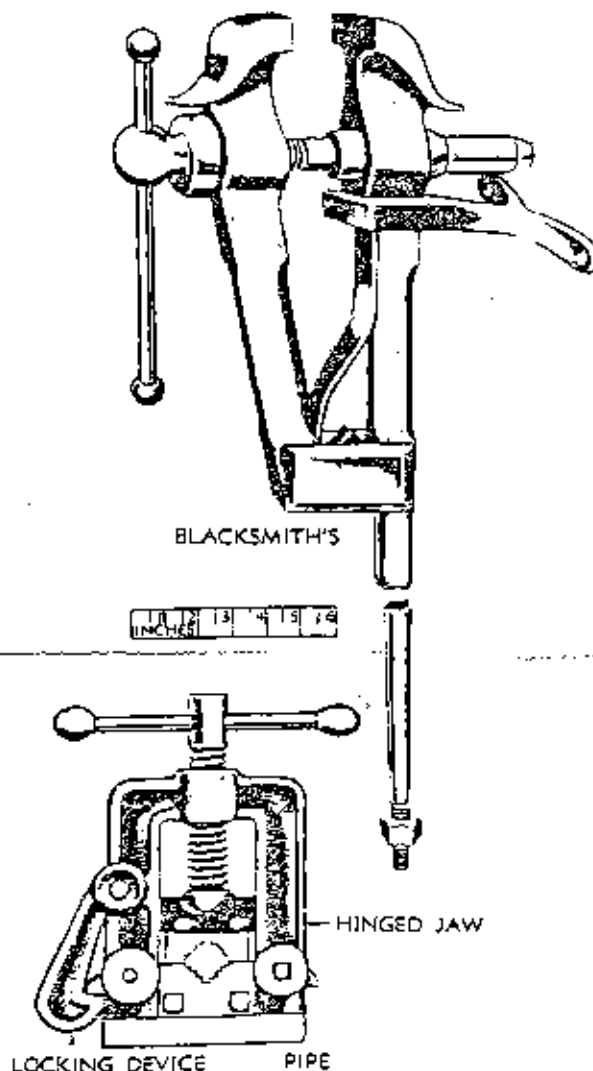


Figure 1-1-100.—Blacksmith's and pipe vises.

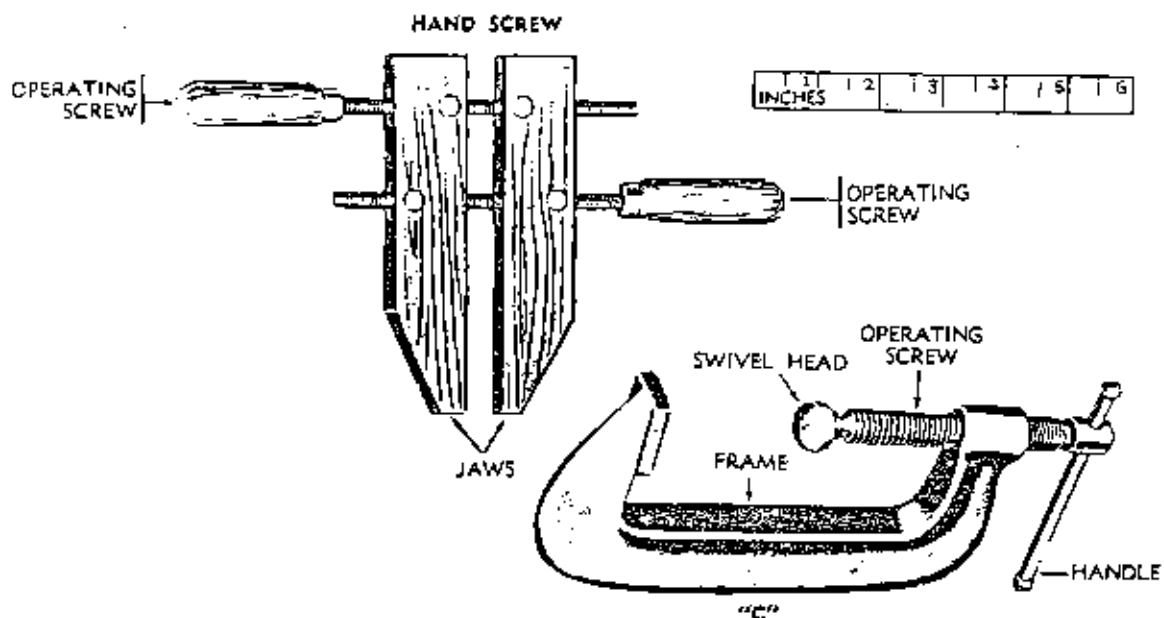


Figure 1-1-101.—C-Clamp and handscrew clamp.

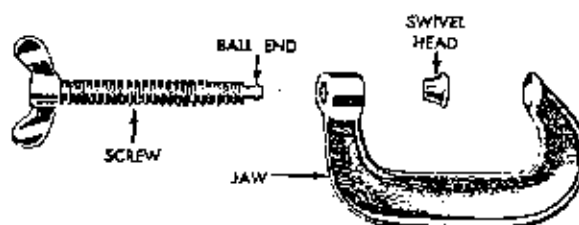


Figure 1-1-102.—C-Clamp, exploded view.

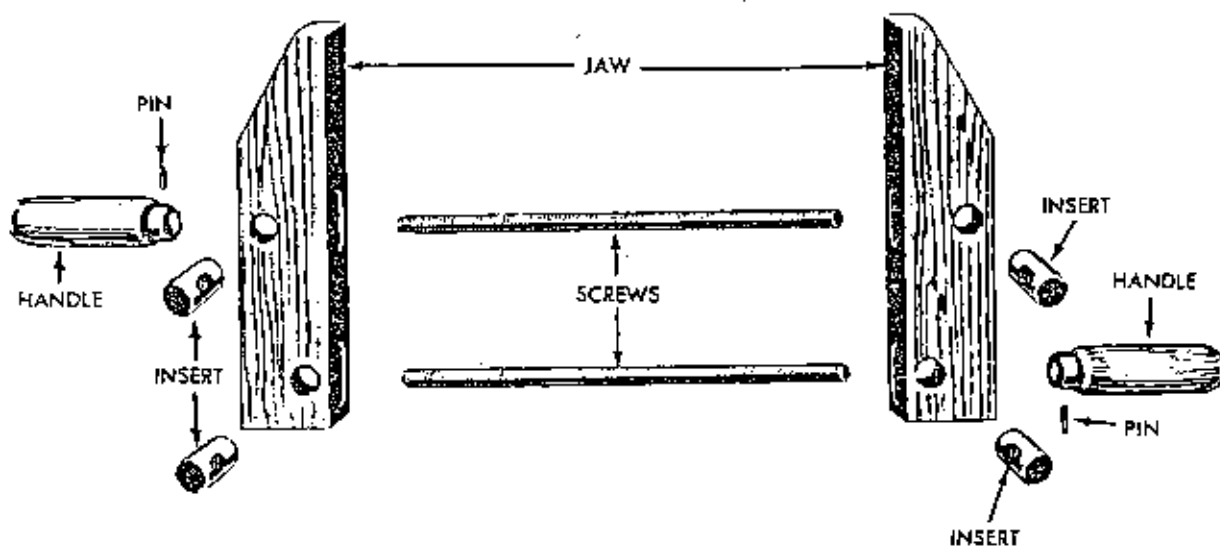


Figure 1-1-103.—Handscrew clamp, exploded view.

SAFETY PRECAUTIONS

When closing the jaw of a vise or clamp, avoid getting any portion of your hands or body between the jaws or between one jaw and the work.

When holding heavy work in a vise, place a block of wood under the work as a prop to prevent it from sliding down and falling on your foot.

Do not open the jaws of a vise beyond their capacity, as the movable jaw will drop off, causing personal injury and possible damage to the jaw.

SOLDERING IRONS

Soldering is joining two pieces of metal by adhesion. The soldering iron is the source of heat for melting solder and heating to the proper temperature the parts to be joined.

There are two general types of soldering irons in use. They are the electrically heated and the nonelectrically heated. The essential parts of both types are the tip and the handle. The tip is made of copper.

The electric soldering iron (fig. 1-1-104) transmits heat to the copper tip after the heat is produced by electric current which flows through a self-contained coil of resistance wire, called the heating element. Electric soldering irons are rated according to the number of watts they consume when operated at the voltage stamped on the iron. There are two types of tips on electric irons: plug tips which slip into the heater head and, which are held in place by a setscrew, and screw tips which are threaded, and which screw into or on the heater head. Some tips are offset and have a 90-degree angle for soldering joints that are difficult to reach (not illustrated). A nonelectric soldering iron (fig. 1-1-104) is sized according to its weight. The commonly used sizes are the 1/4-, 1/2-, 3/4-, 1-, 1 1/2-, 2-, and 2 1/2-pound irons. The 3-, 4-, and 5-pound sizes are not used in ordinary work. Nonelectric irons have permanent tips and must be heated over an ordinary flame, or with a blowtorch.

Electric iron tips must be securely fastened in the heater unit. The tips must be clean and free of copper oxide. Sometimes the shaft oxidizes and causes the tip to stick in place. Remove the tip occasionally and scrape off the scale. If the shaft is clean, the tip will not only receive more heat from the heater element, but it will facilitate removal when the time comes to replace the tip. After use, hang soldering irons on a rack or place on a shelf. Do not throw irons into a toolbox. When storing irons for long periods of time, coat the shaft and all metal parts with rust-preventive compound and store in a dry place.

GRINDERS AND SHARPENING STONES

A hand bench grinder (fig. 1-1-105) is an axially mounted abrasive wheel with a handcrank

that permits turning the wheel. The grinder is geared so that the wheel spins faster than the crank. This type grinder is clamped onto a bench and is equipped with a rest for alignment of the work when grinding.

The hand valve grinder (fig. 1-1-105) is used to lap engine valves to their seats. It consists of pinion-gearing enclosed in a heavy machined cast iron housing. An external crank handle drives the gears, which rotate a shaft. The end of the shaft is designed to hold any one of three driving blades for use on slotted valves. Non-slotted valves can be driven by a rubber suction cup that is supplied with the grinder, that fits the shaft. Two shafts are furnished: one short and one long.

Keep grinders clean and make certain housing screws are tight. Periodically, drain oil from bench grinder and regrease valve grinder. Flush gear housings and gears with suitable cleaning solvent. Refill with manufacturer's recommended grade of lubricant. Remove rust from external surfaces with crocus cloth. After use, wipe clean and store in a suitable box or on a rack. Make certain all nuts, screws, and bolts are tight. For long periods of storage, lubricate and spread a rust-preventive compound on all metal parts. Wrap grinder in oil-soaked cloth and store in a dry place.

Sharpening stones are divided into two groups, natural and artificial. Some of the natural stones are oil treated during and after the manufacturing processes. The stones that are oil treated are sometimes called oilstones. Artificial stones are normally made of silicone carbide or aluminum oxide. Natural stones have very fine grains and are excellent for putting razorlike edges on fine cutting tools. Most sharpening stones have one coarse and one fine face. Some of these stones are mounted, and the working face of some of the sharpening stones is a combination of coarse and fine grains. Stones are available in a variety of shapes, as shown in figure 1-1-106.

A fine cutting oil is generally used with most artificial sharpening stones, however, other lubricants such as kerosene may be used. When a tool has been sharpened on a grinder or grindstone, there is usually a wire edge or a feather edge left by the coarse wheel. The sharpening stones are used to hone this wire or feather edge off the cutting edge of the tool. Do not attempt to do a honing job with the wrong stone. Use a coarse stone to sharpen large and very dull or nicked tools. Use a medium grain stone to sharpen tools not requiring a finished edge, such as tools for working soft wood, cloth, leather, and rubber. Use a fine stone and an oilstone to sharpen and hone tools requiring a razorlike edge.

Prevent glazing of sharpening stones by applying a light oil during the use of the stone. Wipe the stone clean with wiping cloth or cotton waste after each use. If stone becomes glazed or gummed up, clean with aqueous ammonia or drycleaning solvent. If necessary, scour with aluminum oxide abrasive cloth or flint paper attached to a flat block.

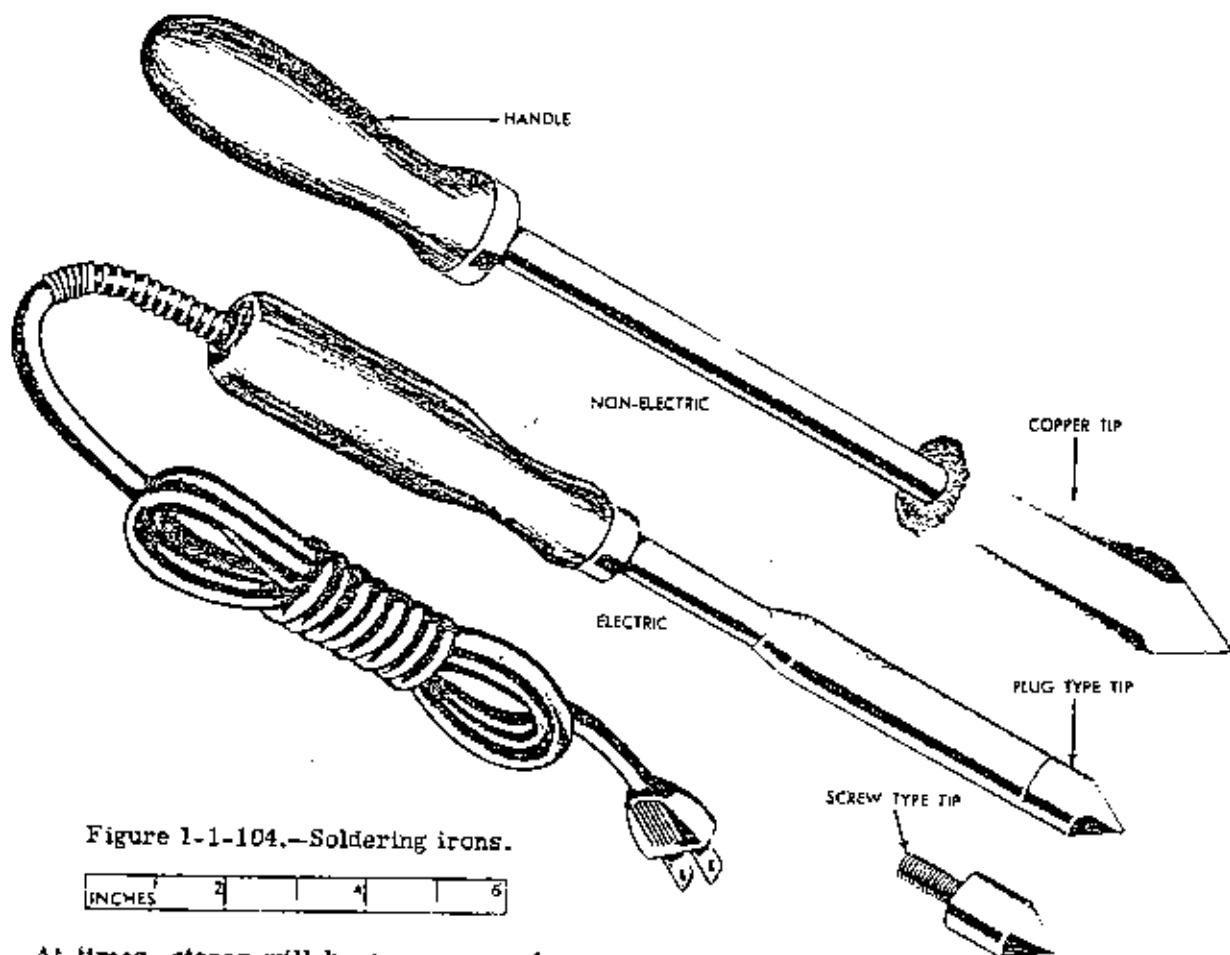


Figure 1-1-104.—Soldering irons.

At times, stones will become uneven from improper use. True the uneven surfaces on an old grinding wheel or on a grindstone. Another method of truing the surface is to lap it with a block of cast iron or other hard material covered with a waterproof abrasive paper, dipping the stone in water at regular intervals and continuing the lapping until the stone is true.

Stones must be carefully stored in boxes or on special racks when not in use. Never lay them down on uneven surfaces or place them where they may be knocked off a table or bench, or where heavy objects can fall on them. Do not store in a hot place.

PIPE AND TUBING CUTTERS AND FLARING TOOLS

Pipe cutters (fig. 1-1-107) are used to cut pipe made of steel, brass, copper, wrought iron, and lead. Tube cutters (fig. 1-1-107) are used to cut tubing made of iron, steel, brass, copper, and aluminum. The essential difference between pipe and tubing is that tubing has considerably thinner walls. Flaring tools (fig. 1-1-108) are used to make single or double flares in the ends of tubing.

Two sizes of hand pipe cutters are generally used.

The No. 1 pipe cutter has a cutting capacity of 1/8 to 2 inches, and the No. 2 pipe cutter has a cutting capacity of 2 to 4 inches.

The pipe cutter (fig. 1-1-107) has a special alloy-steel cutting wheel and two pressure rollers which are adjusted and tightened by turning the handle.

Most TUBE CUTTERS closely resemble pipe cutters, except that they are of lighter construction. A hand screw feed tubing cutter of 1/8-inch to 1 1/4-inch capacity (fig. 1-1-107) has two rollers with cutouts located off center so that cracked flares may be held in them and cut off without waste of tubing. It also has a retractable cutter blade that is adjusted by turning a knob. Other types of tube cutters shown are designed to cut tubing up to and including 3/4 and 1 inch outside diameter. Some cutters have the feed screw covered to protect the threads against dirt and damage.

FLARING TOOLS (fig. 1-1-108) are used to flare soft copper, brass, or aluminum to make 45° flare joints. The single flaring tool consists of a split die block that has holes for 3/16-, 1/4-, 5/16-, 3/8-, 7/16-, and 1/2-inch o.d. tubing, a clamp to lock the tube in the die block, and a yoke that slips over the die block and has a compressor screw and a cone that forms a 45° flare or a bell shape on the end of the tube. The screw has a T-handle. A double flaring tool has the additional feature of adapters that turn in the edge of the tube before a regular 45° double flare is made. It consists of a die block with holes for 3/16-, 1/4-, 5/16-, 3/8-, and 1/2-inch tubing, a yoke with a screw and a flaring cone, plus five adapters for different size tubing, all carried in a metal case.

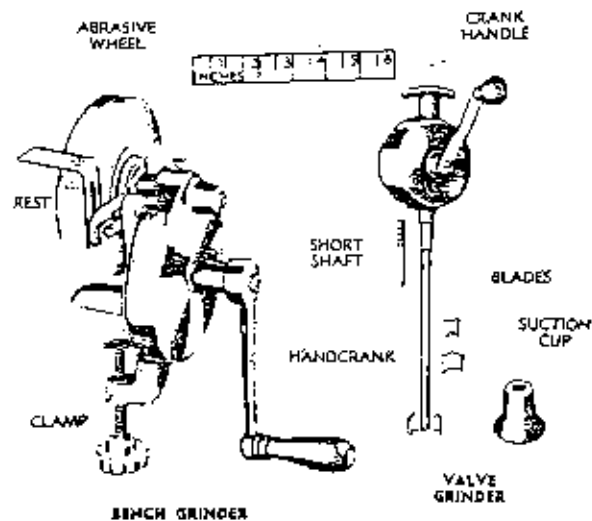


Figure 1-1-105.—Hand grinders.

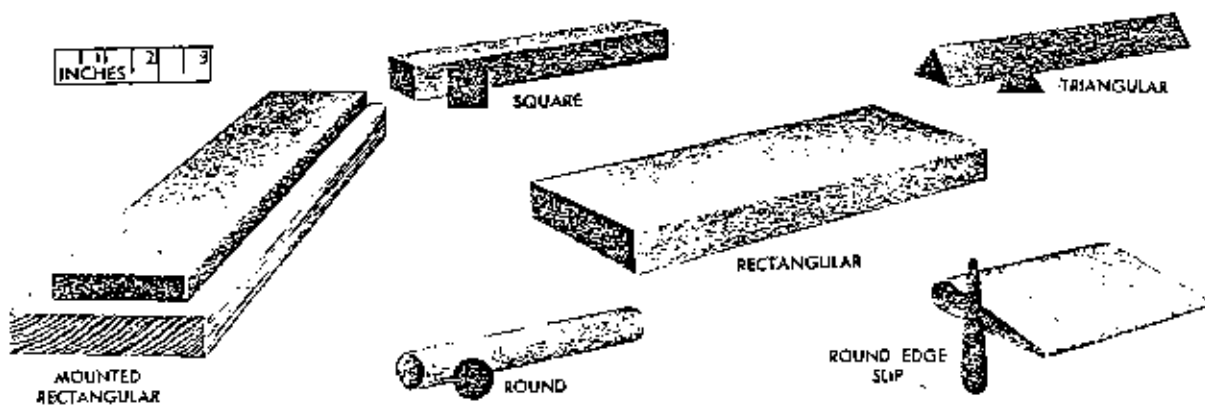


Figure 1-1-106.—Shapes of sharpening stones and oilstones.

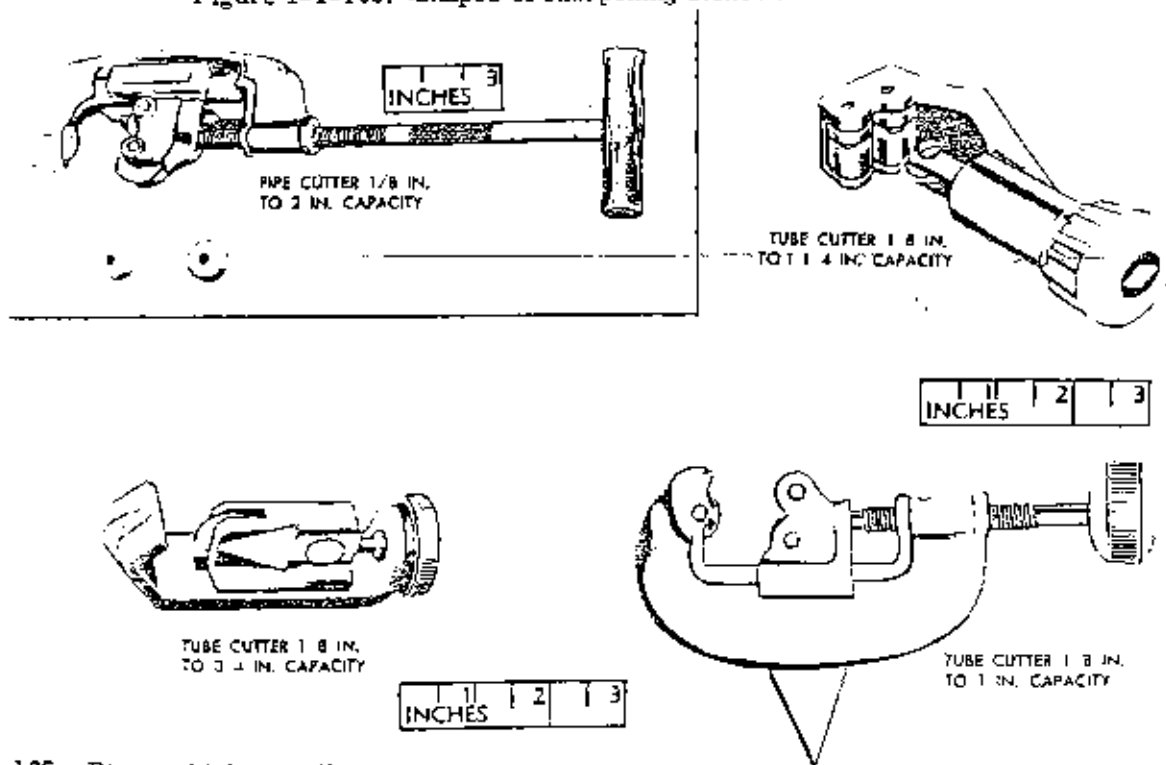


Figure 1-1-107.—Pipe and tubing cutters.

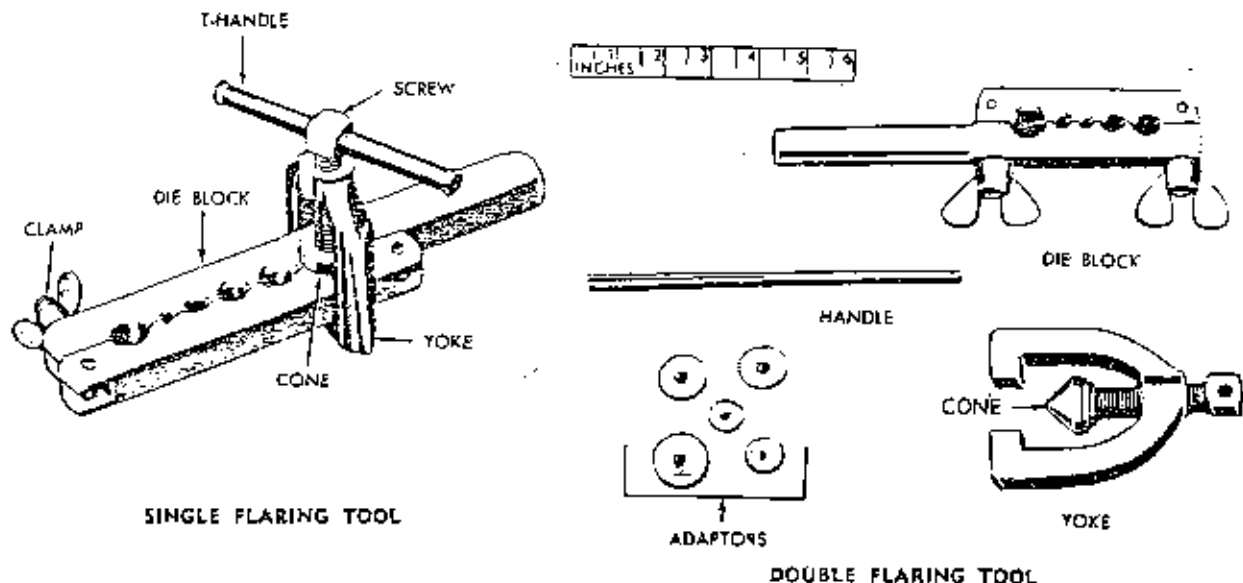


Figure 1-1-108.—Flaring tools.

MISCELLANEOUS TOOLS

Tools described under the heading "miscellaneous tools" are tools that cannot properly be listed under such headings as "metal-cutting tools" or "woodworking tools."

The miscellaneous tools are not likely to be found in any particular toolkit, but will be stored in a central toolroom to be checked out when they are needed. You will find many of these tools mentioned several times throughout the text. This section will give you some tips on nomenclature, where the tools can be used, how they are used, and some safety precautions to be observed when using the tools.

ADZ

The adz (fig. 1-1-109) consists of a hardened steel head which has a square eye at the top and a curved blade at one end. The blade is $3\frac{1}{2}$ to 4 $\frac{1}{2}$ inches wide. It has a wooden handle, which is curved to give balance and to provide the proper angle for cutting.

The adz is used for cutting, shaping, and smoothing of logs when a large amount of wood is to be removed.

Securely block the timber which is to be worked on, to prevent it from slipping, sliding, or rolling. Keep the area being cut clear of chips, because they may deflect the blade and cause it to injure your foot or leg.

To use the adz, the timber to be worked on should be straddled. Grip the handle of the adz with the hands about 12 to 15 inches apart with the tool in front of the body. Make short, chopping strokes by swinging the adz downward and toward the body.

The head of the adz must be removed from the handle for sharpening. Remove the nicks from the edge of the blade by moving the edge back and forth across the wheel of a grindstone.

Then restore the beveled edge to its original shape. Keep the edge square (at a right angle) with the head.

Inspect the handle of the adz frequently for split or broken wood. To insert the handle, seat it into the eye of the head by striking the opposite end of the handle with a mallet.

When not in use, place the adz on its head with the handle standing upward, or hang the adz in a rack. After use, clean the adz head and coat it with light oil before putting it away.

AX

The ax is used to fell or to prune trees, to cut logs and brush, and to split and cut wood. It can also be used for cutting and shaping logs for columns and cribs. Axes are used by fireman and damage control teams to gain entrance into compartments or buildings during a disaster.

In using the ax (fig. 1-1-110), the body weight should be distributed evenly on both legs, with the knees set but not tense, and the feet spread apart at a comfortable distance. The body should be relaxed and free to swing and bend from the hips. The ax may be used with either hand leading, and both positions should be used to prevent tiring provided, of course, you have the ability to swing right-handed or left-handed. With the right hand leading, the left foot should be brought slightly toward the work. The handle is held at the end by the left hand and near the center by the right hand. The ax is then brought up over the shoulder. As it is swung forward, the right hand slides back along the handle toward the left hand so that at the finish of the swing the hands are close together. With the left hand leading on the ax handle, the ax is swung in the same manner, except the positions are reversed.



Figure 1-1-109.—The adz.

Before swinging an ax, make sure no one is in the way of your swing. Clear away any branches, twigs, or other obstruction that might tend to deflect the blade from the target. Keep the blade sharp. A dull blade may be deflected and injure the foot or leg. Keep the blade clear of chips which may deflect the blade. If you are using an ax to cut used timbers make sure that all nails have been removed from the area that is being cut.

It is not necessary to remove the ax handle for sharpening the ax blade. (See fig. 1-1-111.) First remove nicks by moving the edge of the blade back and forth across a grindstone. Then restore the bevel by holding first one side then the other against the stone. The ax bevel should

be slightly convex, or "rolled off." The edge is slightly curved, or fan-shaped, instead of straight across the head of the blade.

When grinding an ax, a wet grindstone should be used. Dip the ax in water frequently to keep it from overheating. Start to grind 2 or 3 inches back from the cutting edge and grind to within about 1/2 inch from the edge. Using a hone or whetstone, sharpen the remaining 1/2 inch and remove all scratches from the area which has been ground. A scratch left on highly tempered steel can cause it to break where it is scratched.

After an ax is used, it should be cleaned, sharpened, and coated with a light film of oil. Store it in a place where it will not fall and injure anyone and so as not to damage the sharp edge.

HATCHET

The half-hatchet, commonly called hatchet, is a chopping and driving tool similar in some respects to a hammer. It is used for light cutting, trimming, and hewing, and (because it is heavier than a hammer) for driving large nails and spikes. (See fig. 1-1-112.) It has a wooden handle and a steel head composed of a hammer-head, and eye, and a blade. Some hatchets have a notch in the blade for pulling nails. Hatchets

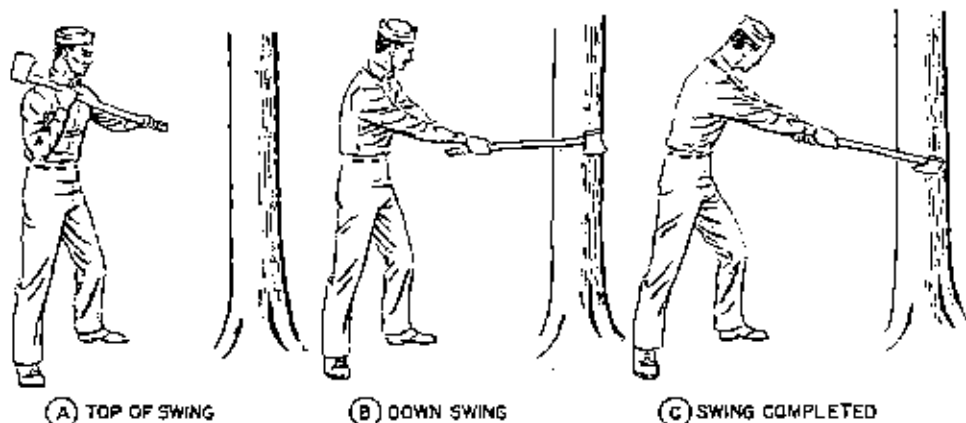


Figure 1-1-110.—Using the Ax.

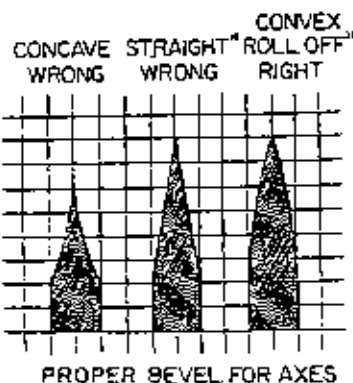
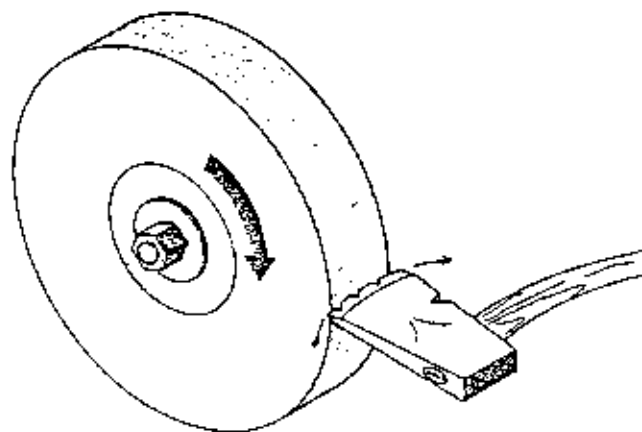


Figure 1-1-111.—Sharpening the Ax.



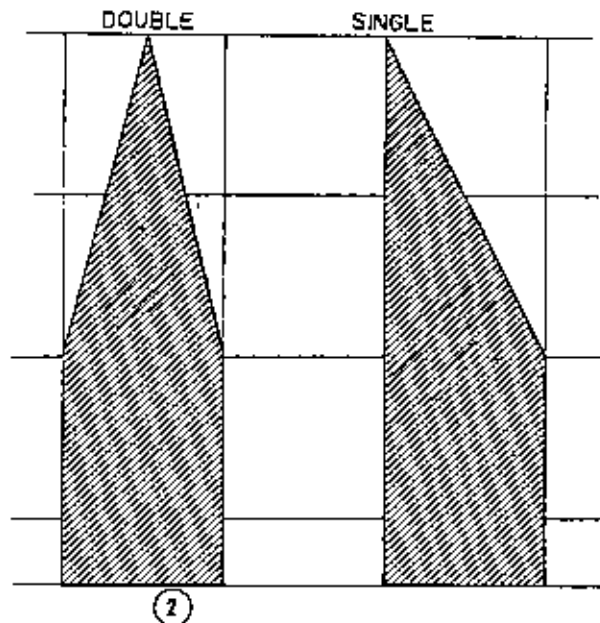
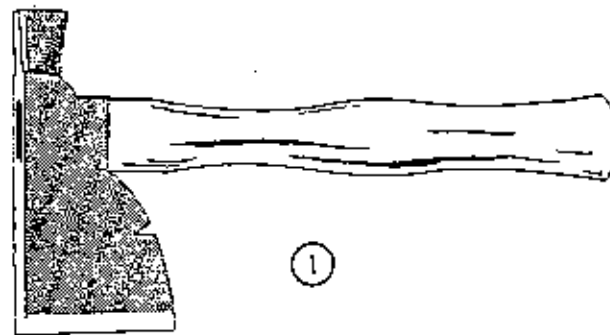


Figure 1-1-112.—Half-hatchet.

are made with two types of cutting edge (fig. 1-1-112): the single bevel and the double bevel. The double bevel is the more common. The single bevel hatchet is ideal for cutting to a line.

To make heavy strokes with the hatchet, grasp the handle with one hand near its end; for light strokes, hold the handle close to the head. The hatchet is used principally to hew to a line with the grain of the wood. To do so, set the wood being hewn on edge and make a series of small, closely spaced cuts at an angle of about 45 degrees across the grain and near the line. Cut away the notched segments by striking with

the grain along the line. In making the scoring cuts, when the grain is irregular, change the direction of the blow to cut across the grain with every stroke.

The care, the maintenance, and the safety rules to be followed when using a hatchet are the same as previously described for the ax.

MASONRY DRILLS

Masonry drills (fig. 1-1-113) frequently called star drills, are shafts of steel with a cutter at one end and a flat face on the other.

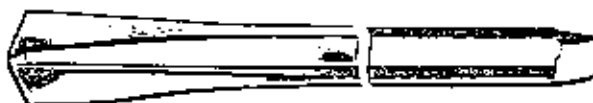


Figure 1-1-113.—Masonry drill.



Figure 1-1-114.—Brick trowel.

Looking at the drill from the end, the cutter resembles four chisels fastened together at their edges. Masonry drills are made in various sizes up to 1 3/4 inches in diameter and 18 to 48 inches in length.

The masonry drill is used for drilling holes in concrete or stone. The cutter end is placed where the hole is to be drilled and the head of the drill is struck with a heavy hammer or sledge. The drill must be rotated after each blow to clear the drilled material from the hole and to keep the drill from binding. In hard stone it is useful to keep the hole wet, both to help clear the hole of drilled material and to keep the drill cool.

The cutting edges are sharpened by grinding on a grinding wheel or by filing, taking care to maintain the original bevel on both sides of the cutting edges. The head of the drill may become burred or broken from the blows from the hammer; it can be restored by grinding or filing.

Always wear goggles when using the masonry drill. Bits of rock or concrete, and rock or concrete dust, will sometimes fly from the material being drilled and may injure your eyes if they are not protected. Keeping the hole wet will lessen the amount of dust raised. Because the drill and the hammer or sledge are both of steel, bits of this material may be broken off from the head of the drill and cause injury.

When holding a masonry drill for another person to strike with a sledge or hammer, always stand at one side of his swing, instead of directly in front of him. This will lessen the danger of injury should the hammer or sledge slip from his grasp or the head of the hammer or sledge come loose.

TROWELS

The BRICK trowel (fig. 1-1-114) is a pointed steel blade about 5 inches wide at the heel and 10 inches long. At the wide end, a wooden handle is fastened to the blade by means of a tang. The tang is bent upward slightly, so that the handle is slightly above the blade in use.

The blade of the trowel is used to scoop and spread mortar, and to chip and cut bricks. The end of the handle is used to tap bricks into place.

Scoop and carry the mortar on the wide part of the blade. This keeps the weight close to the wrist and avoids tiring the hand and wrist. Dump the mortar from the side of the trowel with a quick, chopping motion. Spread it into position with the point of the trowel. With the edge of the trowel cut off any surplus mortar coming out of the joint.

If a beveled or V-shaped joint between the bricks is desired, draw the point of the trowel along the joint, thus forcing the mortar into the joint. The edge of the trowel may be used to chip hardened bits of mortar or other material from the surface of the bricks. To cut a brick with a trowel, strike it sharply with the edge of the trowel at the point where you wish the brick to be cut.

In chipping brick, goggles should be worn to prevent chips or dust from getting into the eyes. If goggles are not available, hold the brick to be cut well away from the face. Do not hold the brick with your hand close to where the cut is being made. You may chop your finger instead of the brick.

The CEMENT trowel (fig. 1-1-115) is a flat rectangular blade about 4 inches wide and 14 inches long. A wooden handle is fastened to the back of the blade in its middle by means of a metal tang and strap.

The cement trowel is used for finishing concrete surfaces. While the concrete is still wet, it may be pushed into place and uneven spots leveled by moving the cement with the edge of the trowel.

To get a smooth surface on the concrete, wait until the concrete has partly set. Then dip the trowel in water and use it much as you would use a flat iron in ironing clothes to smooth out all



Figure 1-1-115.—Cement trowel.

coarse appearing parts of the surface, taking care that the edge of the trowel does not gouge into the surface. The trowel must be kept wet by dipping it into water. Additional water can be brought to the surface of the concrete by slapping the surface with the flat of the trowel while finishing.

Clean all mortar from the trowel, including the handle, by washing it in water after use. If mortar hardens on the blade the trowel becomes useless until it is chipped or cleaned off. Mortar left to harden on the handle will scratch the hands when the trowel is next used. Oil the trowel lightly after it is used and before it is put away.

After working with mortar or cement, wash all cement dust from the skin and remove dirty clothing. The lime in the mortar or cement may burn the skin.

PICKS

The pick (fig. 1-1-116) is a tool that is designed for digging in hard earth. It consists of a steel head set on a wooden handle, which is inserted through an eye in the middle of the head. One end of the head tapers to a sharp point; the other end is chisel shaped.

The pick is used for loosening hard clay or rocky earth so that it may be removed with a shovel. A small amount of prying may be done with a pick; for heavy prying, a bar should be used.

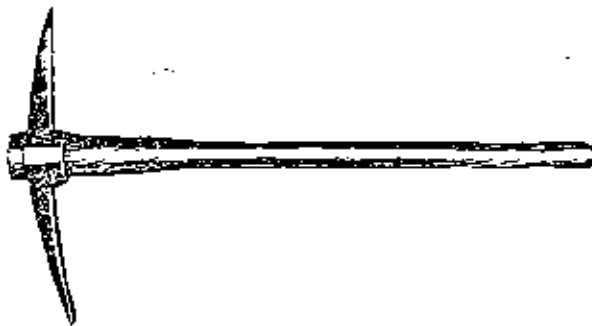


Figure 1-1-116.—Pick.

Do not use a pick in extremely cold weather without first warming the head. Steel becomes brittle in extreme cold, and the head may be broken if used for very heavy blows while it is cold. To sharpen the pick, the head should be removed from the handle. The pick is then sharpened on a grinding machine in the same way as an ax. In the field, where a grinding machine is not available, a coarse file may be used to sharpen the points of a pick.

Observe the same safety precautions when using a pick as you do when using an ax.

SHOVELS

The shovel is a steel blade set on a wooden handle, and is used for moving earth or other material. The blades of some shovels are slightly pointed for easier cutting of earth and the back of the blade is cut off square so that the foot may be used to force the tool into the ground.

There are many types of shovels for various uses. The types generally found are the D-handled round point and the long-handled round point (fig. 1-1-117).

The D-handled round point shovel is designed for light work or for digging in cramped spaces. It has a short handle (about 3 feet in length), at

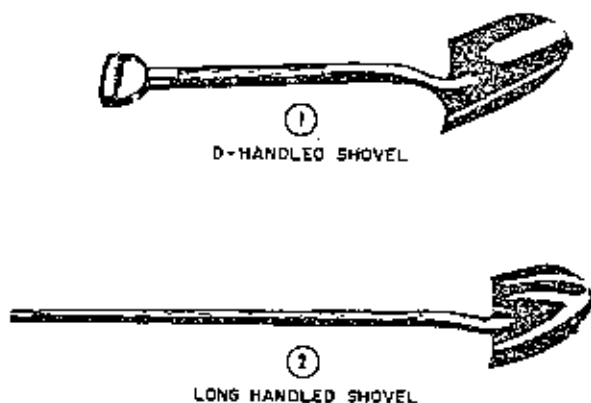


Figure 1-1-117.—Types of shovels commonly used.

the top of which is a D-shaped metal strap, into which is set a short wooden crosspiece for a hand grip.

The long-handled round point shovel is the best for most kinds of heavy work, such as digging trenches or any other digging in which there is sufficient room to swing it. This shovel has no hand grip. Instead the handle is a long (about 5 feet), round pole.

Shovels should not be used for heavy prying; this may break the handle or bend the blade. After use, shovels should be cleaned and oiled. To sharpen the blade after it has been worn, first hammer it into proper shape on a piece of hard wood or an anvil. Then file the point.

To replace the handle on a shovel, cut or grind off the heads of the rivets which hold the blade to the handle. Drive out the rivets and pull the handle from the socket. Insert a new handle and drill rivet holes through it. Drive in and peen the new rivets. If the handle has been broken off close to the socket, it may be necessary to bore the handle out of the socket.

When using a shovel, be sure your working space is free, so that you will not injure another worker when you swing the shovel. Try to throw the material where it will not have to be moved a second time and where it will do no harm.

PINCHBAR

The pinchbar is a steel rod, usually made of 3/4-inch bar stock, with one pointed end and one chisel, or wedge-shaped end. The wedge end is set at a slight angle to the bar. (See fig. 1-1-118A.) The pinchbar is generally used for prying, such as in opening boxes and crates and in loosening boards.

WRECKING BARS

Wrecking bars may be either straight "claw and pinchpoint" or "goosenecked." In any case, the wrecking bar has a claw at one end. The other end is wedge chisel shaped, and bent at a slight angle to the bar (fig. 1-1-118B).

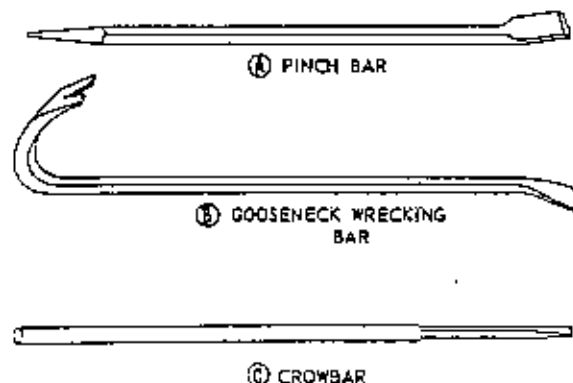


Figure 1-1-118.—Bars.

The wrecking bar is used for prying boards loose and for removing large nails or spikes from boards. The wedge-shaped end is inserted between boards to be removed, and the boards pried loose by exerting leverage on the other end of the bar. The claw is used in the same manner as is the claw on a claw hammer.

The gooseneck bar is usually of lighter weight than the straight wrecking bar. Large spikes should be drawn with the straight bar instead of with the gooseneck, as the lighter gooseneck bar may be bent out of shape in trying to draw too heavy a spike.

CROWBAR

The crowbar is a heavy steel bar about 5 feet in length. One end is square in cross section, and has a wedge-shaped point. The rest of the bar is round and forms the handle (fig. 1-1-118C).

The crowbar is used as a lever for moving heavy objects short distances. It is also used for prying loose heavy boulders and for breaking up hard earth formations in digging. It is a sturdy tool, designed for heavy and hard usage.

COMMON POWER TOOLS

This section of Basic Handtools will acquaint you with the more common types of power tools and equipment. It will also discuss safety precautions, general operating practices, and the necessary care and maintenance of your machines.

Safety cannot be overemphasized when discussing power tools. There are several general rules that will help guide you. Before using a power tool or piece of equipment, remove all loose tools or other objects from it, and make all necessary adjustments. Use only sharp-edged cutting tools, since dull tools are safety hazards.

While operating a power tool, give it full attention. Keep all safety guards in position, and use safety shields or goggles when necessary. Fasten all loose sleeves, neckties, and aprons. Do not disturb or in any way distract another man while he is operating a power tool.

After using a power tool, turn off the power, and clean the tool. Remove all waste and scraps from the deck around it.

PORTABLE ELECTRIC POWER TOOLS

Portable electric power tools are tools that can be easily moved from place to place with a minimum of effort. These are probably the most used of all power tools. Some of the most common portable electric power tools that you will use are drills, hammers, sanders, grinders and saws.

When using any electric power tool make sure the source of power is of the correct voltage. If an electric tool is designed to operate on 115-

volts never plug it into any other power source. The switch on the tool must be in the "OFF" position before it is plugged in. Make sure the cord and plug are in good condition and that the tool is properly grounded before using it.

DRILLS

The portable electric drill is probably the most frequently used portable power tool.

It is especially designed for drilling holes in wood or metal with speed and ease. But today the electric drill has practically developed into a motorized shop that you can hold in one hand. There are so many different types of electric drills with so many diversified accessories that you can add, that they can be used for many different jobs. Sanding, sawing, buffing, polishing, screw-driving, wire brushing, paint mixing—these are samples of possible uses.

Portable electric drills commonly used have capacities for drilling holes in steel from 1/16 inch up to 1 inch in diameter. The sizes of portable electric drills are classified by the maximum size straight shank drill it will hold. That is, a 1/4 inch electric drill will hold a straight shank drill up to and including 1/4 inch.

Figure 1-2-1 shows two popular types of spade handle electric drills. The handles may also be in the shape of a pistol grip. Some of the heavy duty type drills have a provision for an additional projecting bar which can be mounted for applying added feed pressure. Most important when choosing a drill for a job are the revolutions per minute (rpms) and power it will deliver. You will find that the speed of the drill motor decreases with an increase in size, primarily because the larger units are designed to turn larger cutting tools or to drill in heavy

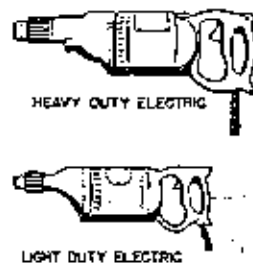


Figure 1-2-1.—Portable electric drills.

materials, and both these factors rule for slower speed.

If you are going to do heavy work, such as drilling in masonry or steel, then you would probably need to use a drill with a capacity of 3/8 inch or 1/2 inch. If most of your drilling will be forming holes in wood or small holes in sheet metal, then a 1/4-inch drill will probably be adequate.

The chuck is the clamping device into which the drill is inserted. Nearly all electric drills are equipped with a three-jaw chuck. Some of

the drill motors have a hand-type chuck that you tighten or loosen by hand but most of the drills used have gear-type, three-jaw chucks which are tightened and loosened by means of a chuck key, shown in figure 1-2-2. Never leave the chuck key in the chuck at any time. Always remove the key IMMEDIATELY after you use it. Otherwise the key will fly loose when the drill motor is started and may cause serious injury to you or one of your shipmates. The chuck key is generally taped on the cord of the drill; but if it is not, make sure you put it in a safe place where it will not get lost.

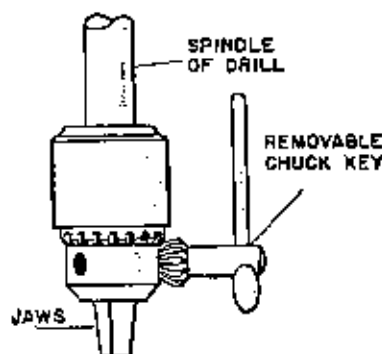


Figure 1-2-2.—Three jaw chuck and chuck key.

All electric drills have some sort of a system for grounding. Make sure that the ground connection is properly made before turning on the drill motor. Proper grounding will prevent injury to you in the event that the internal wiring becomes shorted to the motor housing. Figure 1-2-3 shows one type of ground connection, however, a three prong plug and receptacle should be used when available.

If you must use a portable electric drill at some distance from the source of power make sure you use an extension cord of proper size to prevent excessive voltage drop. You can check with the electricians in the electric shop for this information.

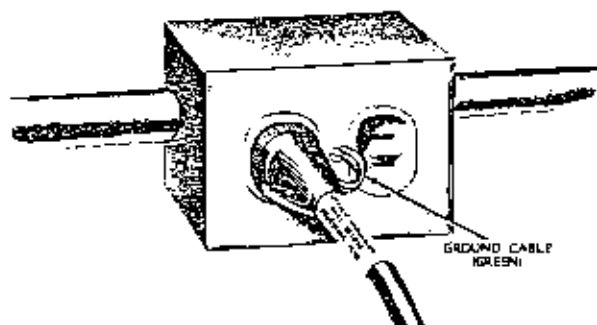


Figure 1-2-3.—Proper grounding of portable electric tool.

All portable electric drills have controls similar to the ones shown on the 1/4-inch drill in figure 1-2-4. This drill has a double pole momentary contact trigger switch located in the pistol grip handle. The switch trigger is squeezed to start the electric drill and released to stop it.

SANDERS

Portable sanders are tools designed to hold and operate abrasives for sanding wood, plastics and metals. Power sanders have made the finishing of wood and metal surfaces easy and fast. Power sanders are widely used to prepare surfaces for paint. The most common types are the DISK sander, BELT sander and RECIPROCATING ORBITAL sander.

The safety precautions to be observed while operating electric sanders are much the same as for the portable electric drill. That is, make sure the tool is properly grounded and in good operating condition prior to operation.

Safety goggles must be worn when operating any tool where dust and flying particles are produced. When sanding some materials, for example, reinforced plastics, respiratory precautions must be observed.

Disk Sander

The disk sander (fig. 1-2-5) is much like a portable drill with an abrasive disk attached. It has a straight type rear grip and a detachable side handle. The straight type rear handle has a slide button switch located on top. The disk sanders come in many different sizes but the most common ones will accommodate a 6- or 7-inch sanding pad.

Electric disk sanders are especially useful on work where a large amount of material is to be removed fast or where a mirror smooth finish is not required.

The electric disk sander is also a handy tool for preparing a surface for paint but great care must be taken when using this machine. The disk should be moved smoothly and lightly over the surface. Never allow the disk to stay in one place too long because it will cut into the metal or wood.

Belt Sander

The belt sander is commonly used for surfacing lumber such as for interior trim, furniture or cabinets. It was once a laborious job to do this work by using a plane and by hand sanding. Wood floors are almost always made ready for final finishing by using a belt sander.

Portable belt sanders (fig. 1-2-6) are built in sizes from 3/4 to 1 1/4 horsepower and most of them can be operated from any standard electric socket. Always check the specifications of the

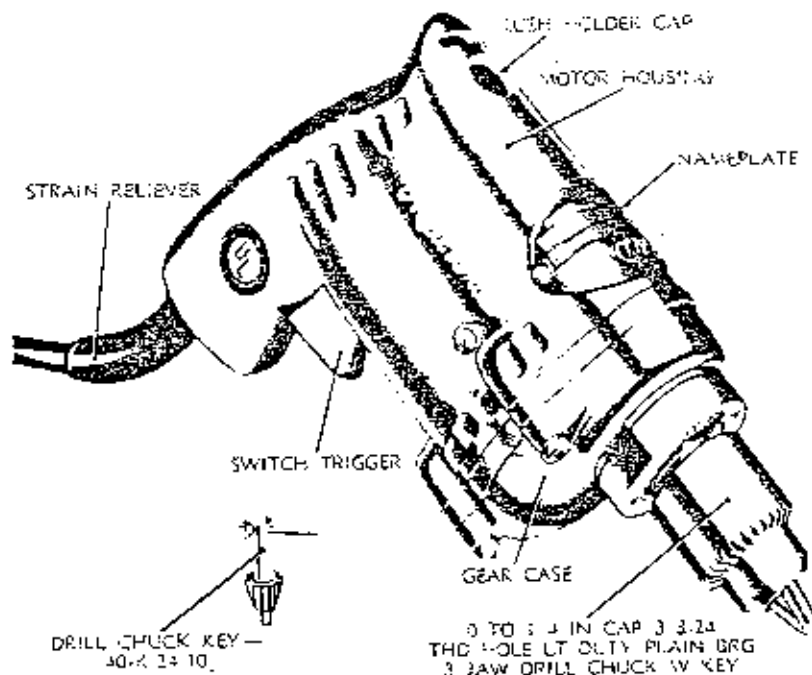


Figure 1-2-4.—1/4-inch portable electric drill.

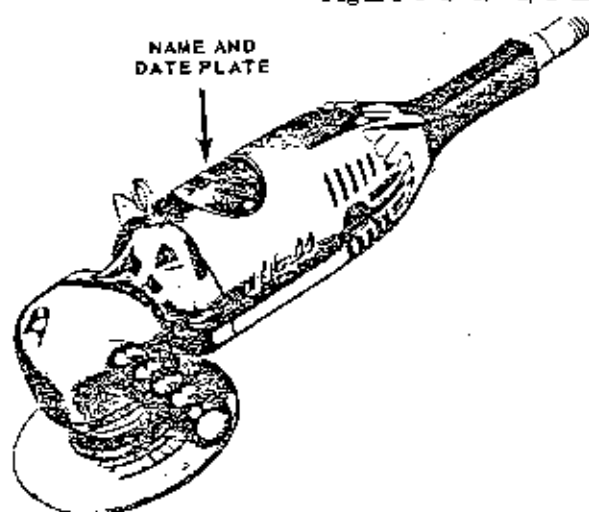


Figure 1-2-5.—Portable electric sander.

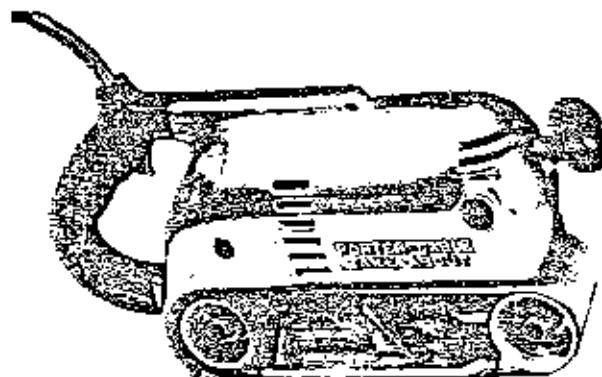


Figure 1-2-6.—Portable belt sander.

sander that you are going to use before plugging it in to make sure the power source and the specifications on the sander correspond.

The portable belt sanders use endless sanding belts that can be obtained in many different grits. The belts are usually 2, 3 or 4 inches wide and can be easily changed when they become worn or when you want to use a different grade (grit) of sanding paper. The weights of the sanders run from 8 lbs up. Therefore very little pressure needs to be applied when you are doing sanding operations. Some types of sanders are provided with a bag that takes up the dust that is produced.

Orbital Sander

The orbital sander is so named because of the action of the sanding pad. The pad moves in a tiny orbit, with a motion that is hardly discernible, so that it actually sands in all directions. This motion is so small and so fast that, with fine paper mounted on the pad, it is nearly impossible to see any scratches on the finished surface.

The pad, around which the abrasive sheet is wrapped, usually extends beyond the frame of the machine so it is possible to work in tight corners and against vertical surfaces.

Some models of the orbital sanders have a bag attached to catch all dust that is made from the sanding operation. The precautions for operation, maintenance and grounding the orbital sander are the same as for the disk sander.

Orbital sanders (pad sanders) do not remove as much material as fast as the belt sander or disk sander but do a good job on smoothing a surface for finishing. If both a belt or disk sander and an orbital sander are available you

should use the belt or disk sander for rough, preliminary work and the orbital sander for finishing.

Orbital sanders (fig. 1-2-7) are made in several different sizes. The sandpaper used on the sander may be cut to size from a bulk sheet of paper or may be available in the correct size for the sander you have. The paper is wrapped around a pad on the sander and is fastened to the pad by means of levers on the front and rear of the sander. The lever action fasteners make changing the paper easy and quick.

PORTABLE GRINDERS

Portable grinders are power tools that are used for rough grinding and finishing of metallic surfaces. They are made in several sizes, however, the one used most uses a grinding wheel with a maximum diameter of 6 inches. (See fig. 1-2-8.)

The abrasive wheels are easily replaceable so that different grain size and grades of abrasives can be used for the varying types of surfaces to be ground and the different degrees of finish desired.

The grinder is driven by a universal-current motor. The grinding wheels are driven by the grinding-wheel drive spindle which receives its drive from the motor through a set of gears. The universal-current motor can be run off either AC or DC current.

The nameplate for the portable grinder is attached to the top of the motor housing. It contains the following data: manufacturer's name and address, model number, no-load rpm, serial number, AC cycles per second, amperage, number of AC phases, voltage, type of current required, and a warning concerning the need for grounding the grinder when in use.

There is a flexible shaft attachment that is available for most portable grinders. This shaft is attached by removing the grinding wheel then attaching the shaft to the grinding wheel drive spindle. The grinding wheel can then be attached to the end of the flexible shaft. This attachment is invaluable for grinding surfaces in hard to reach places.

It is particularly important that the ground conductor be connected to ground when there is presence of water in the work area. This will prevent possible injury to you in the event that the internal wiring of the grinder becomes shorted to the field case.

The wheel guard on the grinder should be positioned so that abrasive dust and metal particles will be deflected away from your face.

Before you turn the grinder on, make sure the abrasive grinding wheel is properly secured to the grinder spindle and not cracked or damaged.

PORTABLE CIRCULAR SAW

The portable circular saw, often called Skil-saw, is one of the most used power machines by people who have occasion to work with wood. They are becoming more and more popular because of the time and labor they save, the precision with which they work, and their ease of handling and maneuverability.

Because of the many types of portable circular saws in the system, and the changes being made in the design of these saws, only general information will be given in this section. Information concerning a particular saw can be found by checking the manufacturer's manual.

The sizes of portable electric saws range from one-sixth horsepower with a 4-inch blade to one-and-one half horsepower with a 14-inch blade. They are so constructed that they may

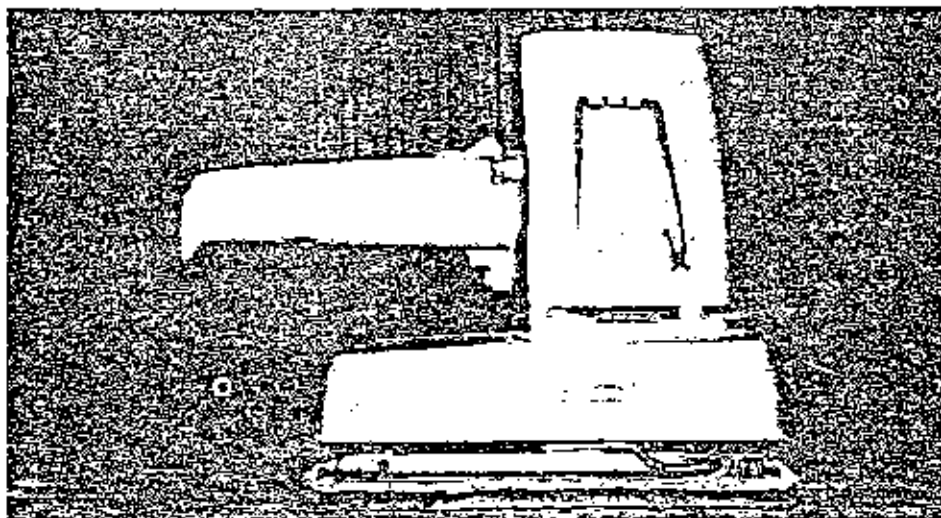


Figure 1-2-7.—Orbital sander.

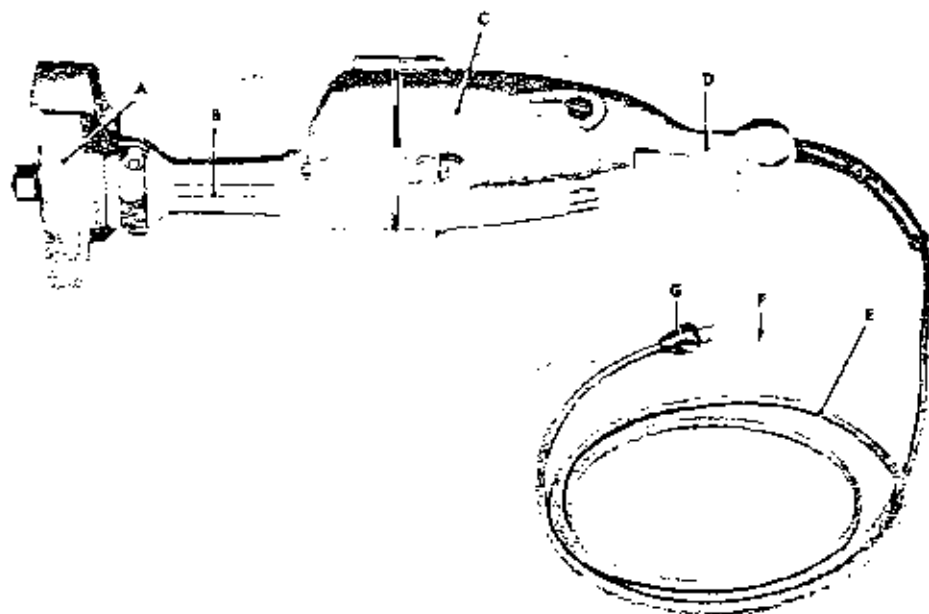


Figure 1-2-8.—Portable grinder.

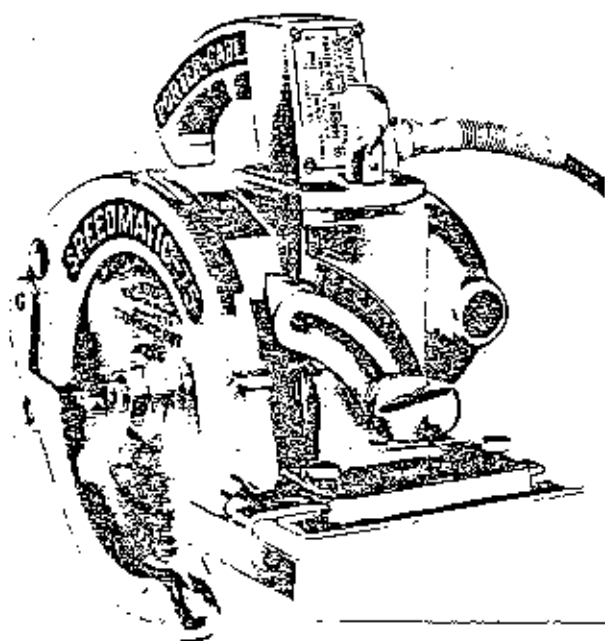


Figure 1-2-9.—Portable electric circular saw.

be used as a carpenter's handsaw, both at the job site or on a bench in the woodworking shop.

The portable electric saw (fig. 1-2-9) is started by pressing a trigger inserted in the handle and stopped by releasing it. The saw will run only when the trigger is held.

Most saws may be adjusted for crosscutting or for ripping. The rip saw guide is shown at (A, fig. 1-2-9). In this illustration it is turned up out of the way since the saw is being used as a crosscut saw. A guideline for crosscutting may be marked across the board as at B or the cross-cut guide (F, fig. 1-2-9) may be used. When one

straight side of this guide is held against the edge of the board, the other straight side will be at a right angle to this edge. The base plate of the saw can then slide along this guide and the saw will produce a square cut.

The depth of the cut is regulated by the adjusting thumbscrew shown at C. The adjustment for angle cutting is shown at D. This permits the base to be tilted in relation to the saw. A rapid adjustment may be made by the use of the graduated scale marked in degrees on the quadrant (E).

The bottom plate of the saw is wide enough to provide the saw with a firm support on the lumber being cut. The blade of the saw is protected by a spring guard which opens when lumber is being cut but snaps back into place when the cut is finished. Many different saw blades may be placed on the machine for special kinds of sawing. By changing blades almost any building material from slate and corrugated metal sheets to fiberglass can be cut.

Most portable electric saws are equipped with universal motors that will operate on either AC or DC current and require 115 volts. As with other portable electric tools, they must be grounded before they are turned on.

The portable electric saw is one of the most dangerous power tools in existence when it is not properly used. Make sure the board you are sawing is properly secured so it will not slip or turn. After making a cut be sure the saw blade has come to a standstill before laying the saw down.

When using an electric saw remember that all the blade you can normally see is covered; the portion of the blade that projects under the board being cut is not covered. The exposed teeth under the work are dangerous and can

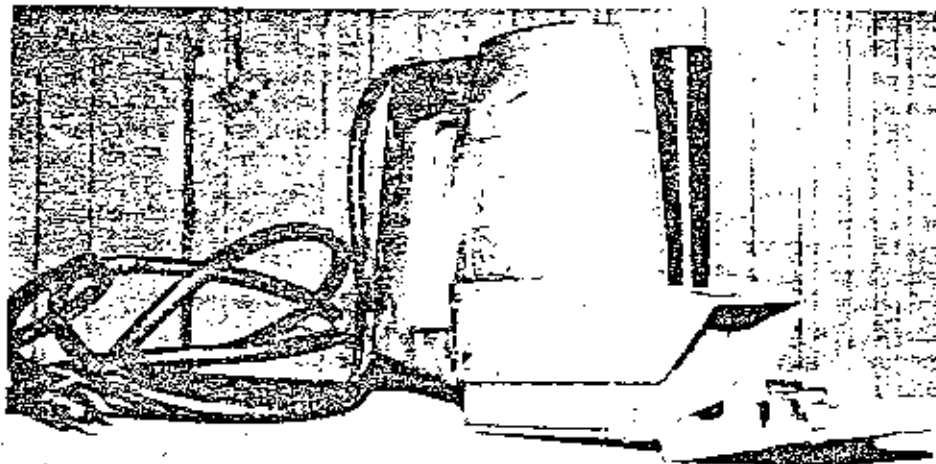


Figure 1-2-10.—Portable electric saber saw.

cause serious injury if any part of your body should come into contact with them.

Make sure the blade of a portable circular saw is kept sharp at all times. The saw blade will function most efficiently when the rate of feed matches the blade's capacity to cut. You will not have to figure this out—you will be able to feel it. With a little practice you will know when the cut is smooth and you will know when you are forcing it. Let the blade do its own cutting. The tool will last longer and you will work easier because it is less fatiguing.

SABER SAW

The saber saw (fig. 1-2-10) is a power driven jigsaw that will let you cut smooth and decorative curves in wood and light metal. Most saber saws are light duty machines and are not designed for extremely fast cutting. About the same safety precautions must be observed when using the saber saw as for any other portable power tool.

There are several different blades designed to operate in the saber saw and they are easily interchangeable. For fast cutting of wood, a blade with coarse teeth may be used. A blade with fine teeth is designed for cutting metal.

The best way to learn how to handle this type of tool is to use it. Before trying to do a finished job with the saber saw, clamp down a piece of scrap plywood and draw some lines to follow, curved ones as well as straight ones. You will develop your own way of gripping the tool, and this will be affected somewhat by the particular tool you are using. On some tools, for example, you will find guiding easier if you apply some downward pressure on the tool as you move it forward. If you are not firm with your grip, the tool will tend to vibrate excessively and this will roughen the cut. Do not force the cutting faster than the design of the blade allows or you will break the blade. If this happens do not blame the tool.

ELECTRIC IMPACT WRENCH

The electric impact wrench (fig. 1-2-11) is a portable hand-type reversible wrench. The one shown has a 1/2-inch square impact driving anvil over which 1/2-inch square drive sockets can be fitted. Wrenches also can be obtained that have impact driving anvils ranging from 3/8 inch to 1 inch. The driving anvils are not interchangeable, however, from one wrench to another. The reversing ring, located on the rear of the motor housing, is held in place by a brush holder cover.

A pistol-grip handle, which contains the on-and-off trigger switch, is an integral part of the motor housing. The wrench is equipped with a three-cable flexible cord having a male contact plug connector and one ground cable.

The electric wrench with its accompanying equipment (fig. 1-2-12) is primarily intended for applying and removing nuts, bolts, and screws. It may also be used to drill and tap metal, wood, plastics, etc., and drive and remove socket-head, Phillips-head, or slotted-head wood, machine, or self-tapping screws.

When you use an electric wrench that you are not completely familiar with, first check the voltage specifications and make sure the source of power is correct. After connecting the wrench to a suitable power source, depress the on-and-off trigger switch and allow the electric wrench to operate a few seconds, noting carefully the direction of rotation. Release the trigger switch to stop the wrench. Turn the reversing ring located at the rear of the tool; it should move easily in one direction (which is determined by the current direction of rotation). Depress the on-and-off trigger again to start the electric wrench. The direction of rotation should now be reversed. Continue to operate for a few seconds in each direction to be sure that the wrench and its reversible features are functioning correctly. When you are sure the

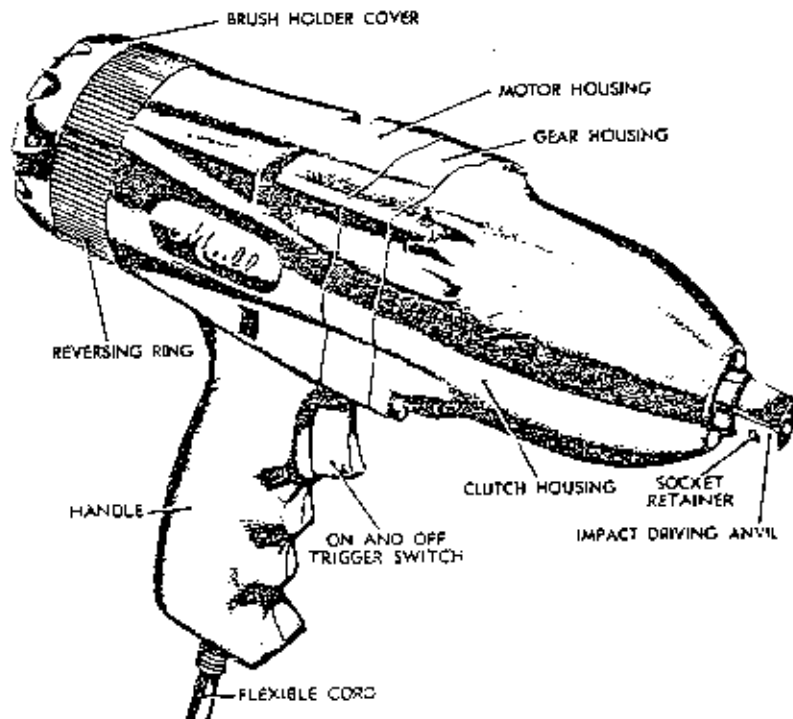


Figure 1-2-11.—Reversible electric impact wrench.

wrench operates properly, place the suitable equipment on the impact driving anvil and go ahead with the job at hand.

SOLDERING GUNS

The soldering gun (fig. 1-2-13) is an induction-type soldering iron. This is not mechanical in the sense that it does not have any moving parts, but is becoming widely used.

The soldering gun operates on any standard electrical outlet and is rated in size by the number of watts it produces. The guns used are rated between 100 and 250 watts. All good quality soldering guns operate in a temperature range of 500 to 600° F. The important difference in gun sizes is not the temperature, but the capacity of the gun to generate and maintain a satisfactory soldering temperature while giving up heat to the joint soldered.

Soldering guns contain a stepdown transformer in their bodies. The transformer secondary output current flows through the tip, causing it to heat. The tip heats only when the trigger is depressed, and then very rapidly. These guns afford easy access to cramped quarters, because of their small tip. Most soldering guns have a small light that is focused on the tip working area.

To prevent damage to the soldering gun, never subject it to heavy mechanical abuse. For instance, if the gun is dropped, or used as a hammer or a pry, the heating element may be broken or shorted or the tip may become bent. Always make certain that the cord does not come in contact with the tip where it can be burned.

The tip of a soldering gun should be removed occasionally to permit cleaning away the oxide scale which forms between the tip and metal housing. Removal of this oxide increases the heating efficiency of the gun. If for any reason the tip does become damaged, replaceable tips are available.

PORTABLE PNEUMATIC POWER TOOLS

Portable pneumatic power tools are tools that look much the same as electric power tools but are powered by compressed air instead of electricity. Because of the limited outlets for compressed air the use of pneumatic power tools is not as widespread as electric tools. Portable pneumatic tools are used most around a shop where compressed air outlets are more readily accessible.

PORTABLE PNEUMATIC DRILL

Portable pneumatic drills are made in several different sizes, however, those most commonly used will accommodate 1/2-inch drills for metal drilling and up to 1-inch drills for wood boring. (See fig. 1-2-14.) The pneumatic drills are intended for drilling or enlarging holes in metal, wood, plastics, etc.

Most pneumatic drills consist of a cast aluminum housing with a pistol-grip handle. There is a built-in air reservoir, a centrifugally actuated governor, a removable air strainer, a reduction gear case, and a rotor having a splined shaft mounted on ball bearings.

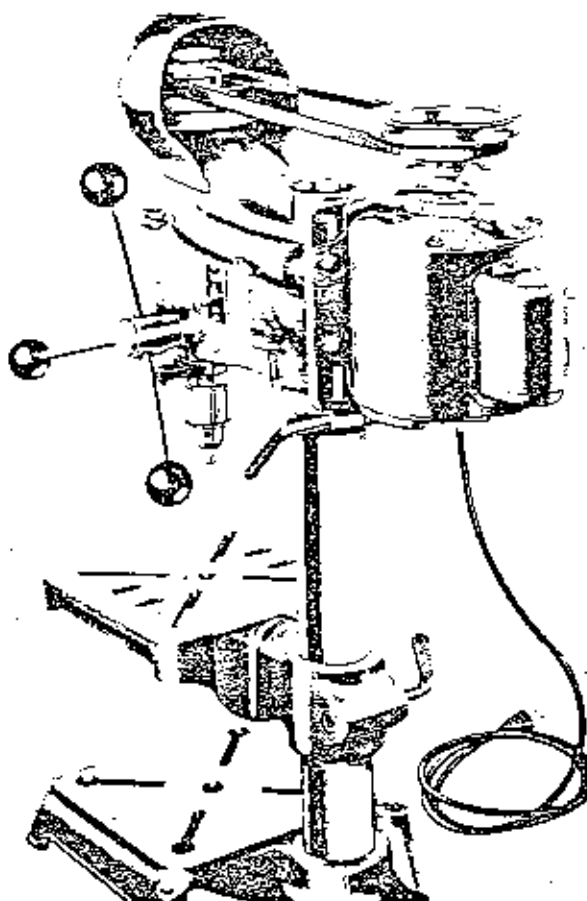


Figure 1-2-18.—Bench-type drill press.

have a capacity to drill holes in metal up to 1 inch in diameter. The driving motors range in size from 1/3 hp to 3 hp.

The motor is mounted to a bracket at the rear of the head assembly and designed to permit V-belt changing for desired spindle speed without removing the motor from its mounting bracket. Four spindle speeds are obtained by locating the V-belt on any one of the four steps of the spindle-driven and motor-drive pulleys.

The controls of drill presses are all similar. The terms "right" and "left" are relative to the operator's position standing in front of and facing the drill press. Forward applies to movement toward the operator. Rearward applies to movement away from the operator.

The toggle switch (fig. 1-2-20) is located on the right side of the head assembly. The switch is single-pole single-throw. Start the motor by placing the switch in the "ON" position.

The spindle and quill feed handles (fig. 1-2-20) radiate from the spindle and quill pinion feed hub which is located on the lower right-front side of the head assembly. Pulling forward and down on any one of the three spindle

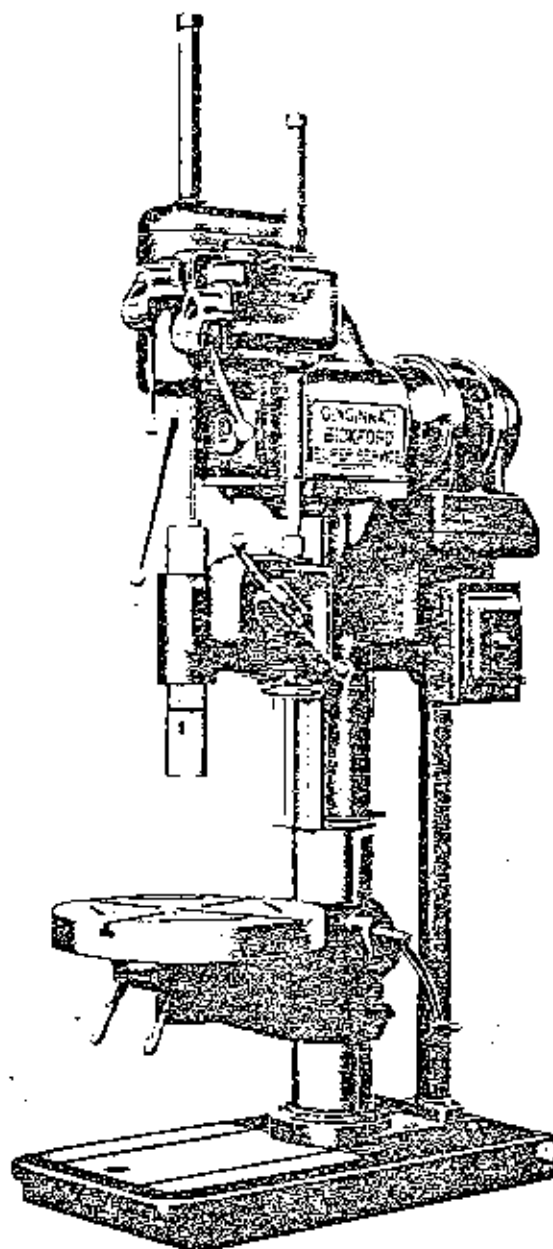


Figure 1-2-19.—Upright-type drill press.

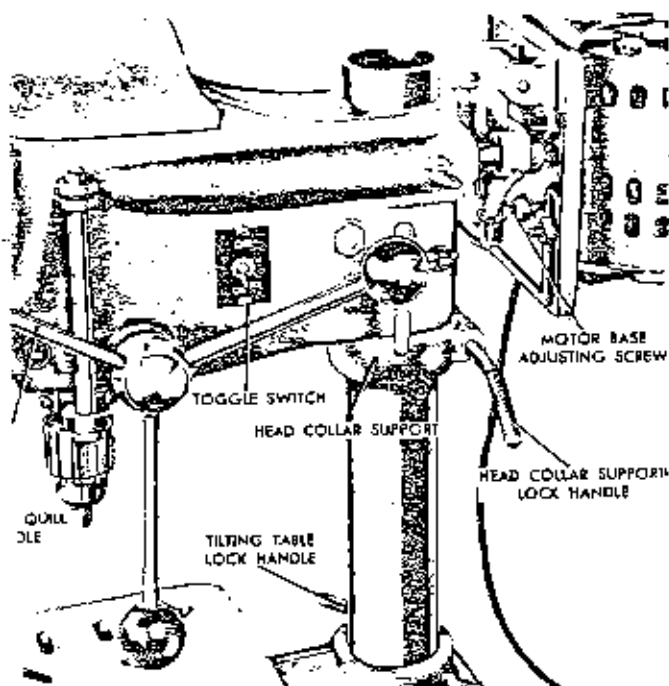
and quill feed handles, which point upward at the time, moves the spindle and quill assembly downward. Release the feed handle and the spindle and quill assembly will return to the retracted or upper position by spring action.

The quill lock handle (fig. 1-2-21) is located at the lower left-front side of the head assembly. Turn the quill lock handle clockwise to lock the quill at a desired operating position. Release the quill by turning the quill lock handle counterclockwise. However, in most cases, the quill lock handle will be in the released position.

The head lock handle (fig. 1-2-21) is located at the left-rear side of the head assembly. Turn the head lock handle clockwise to lock the head assembly at a desired vertical height on the bench column. Turn the head lock handle

counterclockwise to release the head assembly. When operating the drill press, the head lock handle must be tight at all times.

The head collar support lock handle (fig. 1-2-20) is located at the right side of the head collar support and below the head assembly. The handle locks the head collar support, which secures the head vertically on the bench column, and prevents the head from dropping when the head lock handle is released. Turn the head collar support lock handle clockwise to lock the support to the bench column and



1-2-20.—Drill-press controls—right side view.

counterclockwise to release the support. When operating the drill press, the head collar support lock handle must be tight at all times.

The tilting table lock handle (fig. 1-2-20) is located at the left-rear side of the tilting table bracket. Turn the tilting table lock handle counterclockwise to release the tilting table bracket so it can be moved up and down or around the bench column. Lock the tilting table assembly at desired height by turning the lock handle clockwise. When operating the drill press, the tilting table lock handle must be tight at all times.

The tilting table lockpin (S, fig. 1-2-22) is located below the tilting table assembly (T, fig. 1-2-22). The lockpin secures the table at a horizontal or 45° left or right from the horizontal position. To tilt the table left or right from its horizontal position, remove the lockpin and turn the table to align the lockpin holes. Insert the lockpin through the table and bracket holes after desired position is obtained.

The depth gage rod adjusting and locknuts (BB and CC (fig. 1-2-22) are located on the depth gage rod (Z, 1-2-22). The purpose of the adjusting and locknuts is to regulate depth drilling. Turn the adjusting and locknut clockwise to decrease the downward travel of the spindle. The locknut must be secured against the adjusting nut when operating the drill press.

When operating a drill press make sure the drill is properly secured in the chuck and that the work you are drilling is properly secured in position. Do not remove the work from the tilting table or mounting device until the drill press has stopped.

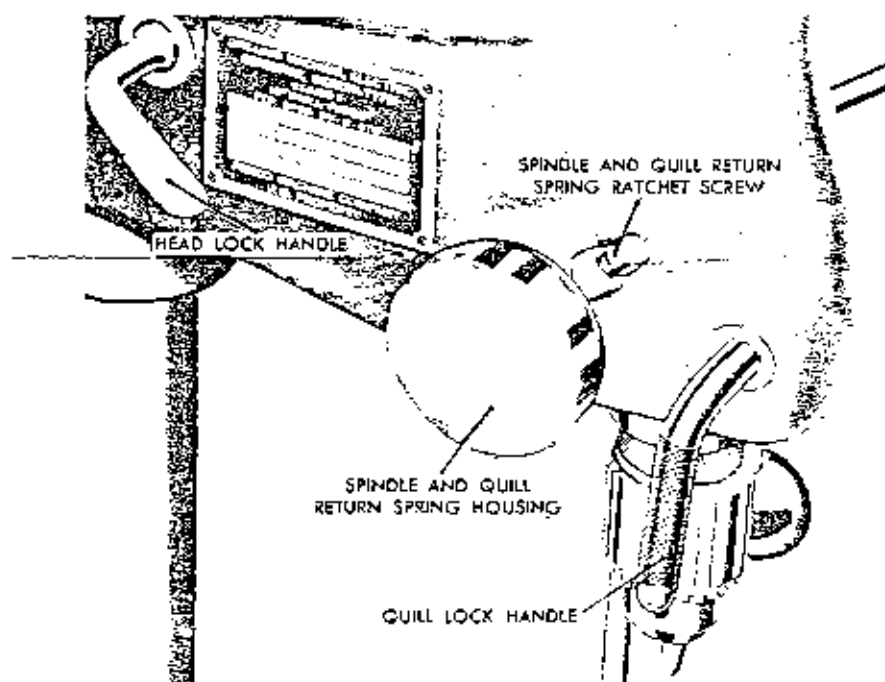
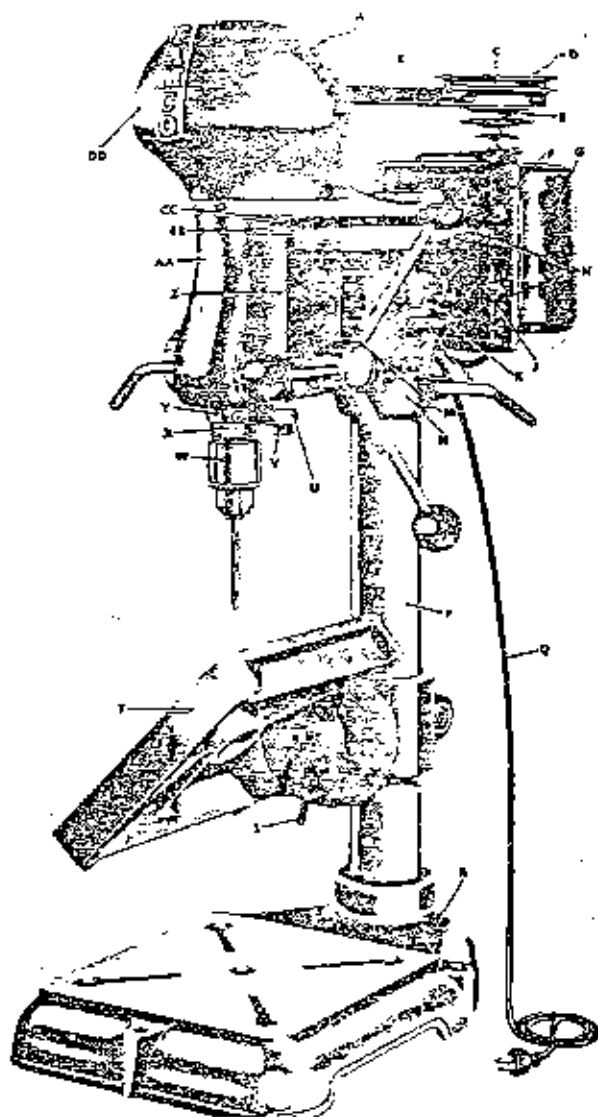


Figure 1-2-21.—Drill press controls—left side view



- A Spindle driven pulley
- B V-Belt
- C Motor drive pulley
- D 1/8 sq x 1 sq-end key
- E No 10-24 x 5/8 hdl's set screw
- F Motor bracket stud thumbscrew
- G Motor
- H Motor base and bracket assy
- J 1/4-20NC 2 x 1 sq-neck rd-hd carriage bolt and 1/4-20NC-2 sq nut
- K Drill chuck key
- L Drill chuck key bracket
- M Toggle switch plate
- N Head collar support
- P Bench column
- Q Cord
- R Bench base
- S Tilting table lockpin
- T Tilting table assy
- U Depth gage rod bracket
- V Hex nut
- W Drill chuck
- X Chuck knockout collar
- Y Spindle and quill assy
- Z Depth gage rod
- AA Head assy
- BB Depth gage rod adjusting nut
- CC Depth gage rod locknut
- DD Spindle driven pulley guard

Figure 1-2-22.—Drill press nomenclature.

just as necessary in accordance with the manufacturer's manual. Make sure the electric cord is securely connected and that the insulation is not damaged, chafed, or cracked.

While the drill press is operating, be alert for any sounds that may be signs of trouble, such as squeaks or unusual noise. Report any unusual or unsatisfactory performance to the petty officer in charge of the shop.

After operating a drill press, wipe off all dirt, oil, and metal particles. Inspect the V-belt to make sure no metal chips are imbedded in the driving surfaces.

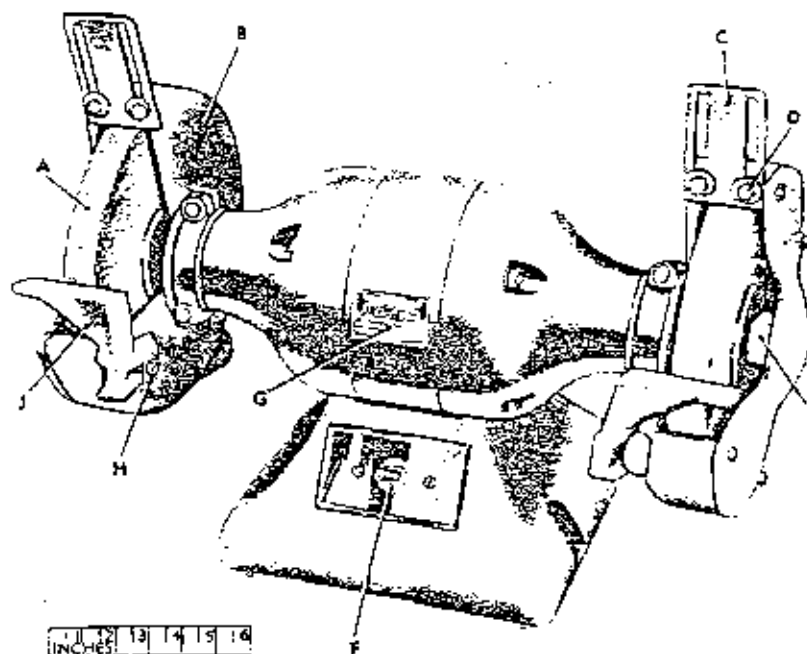
Operate the spindle and quill and feed handles with a slow, steady pressure. If too much pressure is applied, the V-belt may slip in the pulleys, the twist drill may break, or the starting switch in the motor may open and stop the drill press. If the motor should stop because of overheating, the contacts of the starting switch will remain open long enough for the motor to cool, then automatically close to resume normal operation. Always turn the toggle switch to "OFF" position while the motor is cooling.

Check occasionally to make sure all locking handles are tight, and that the V-belt is not slipping.

Before operating any drill press, visually inspect the drill press to determine if all parts are in the proper place, secure, and in good operating condition. Check all assemblies, such as the motor, head, pulleys, and bench for loose mountings. Check adjustment of V-belt and ad-

BENCH GRINDER

The electric bench grinder (fig. 1-2-23) is designed for hand grinding operations, such as sharpening chisels or screw drivers, grinding drills, removing excess metal from work, and smoothing metal surfaces. It is usually fitted with both a medium grain and fine grain abrasive wheel; the medium wheel is satisfactory for rough grinding where a considerable quantity of metal has to be removed, or where a smooth finish is not important. For sharpening tools or grinding to close limits of size, the fine wheel should be used as it removes metal slower, gives the work a smooth finish and does not generate enough heat to anneal the cutting edges.



- A—GRINDING ABRASIVE WHEEL
- B—LEFT HAND WHEEL GUARD ASSY
- C—EYE SHIELD
- D—5/16-24NF-2 X 7/8 HEX-HD CAP SCREW
- E—RIGHT HAND WHEEL CLAMP NUT
- F—TOGGLE SWITCH
- G—NAME PLATE
- H—5/16-24NF-2 X 1 HEX-HD CAP SCREW
- J—LEFT HAND TOOL REST

Figure 1-2-23.—Electric powered grinder.

When a deep cut is to be taken on work or a considerable quantity of metal removed, it is often practical to grind with the medium wheel first and finish up with the fine wheel. Most bench grinders are so made that wire brushes, polishing wheels, or buffing wheels can be substituted for the removable grinding wheels.

To protect the operator during the grinding operation, an eye shield and wheel guard are provided for each grinding wheel. A tool rest is provided in front of each wheel to rest and guide the work during the grinding procedure. The rests are removable, if necessary, for grinding odd-shaped or large work.

When starting a grinder, turn it on and stand to one side until the machine comes up to full speed. There is always a possibility that a wheel may fly to pieces when coming up to full speed. Never force work against a cold wheel; apply work gradually to give the wheel an opportunity to warm. You thereby minimize the possibility of breakage.

Handle grinding wheels carefully. Before replacing a wheel always check it for cracks. Make sure that a fiber or rubber gasket is in place between each side of the wheel and its retaining washer. Tighten the spindle nut just enough to hold the wheel firmly; if the nut is tightened too much the clamping strain may damage the wheel. When selecting a replace-

ment wheel, ascertain that the grinder will not exceed the manufacturer's recommended speed for the wheel.

When grinding, always keep the work moving across the face of the wheel; grinding against the same spot on the wheel will cause grooves to be worn into the face of the wheel. Keep all wheel guards tight and in place. Always keep the tool rest adjusted so that it just clears the wheel and is at or just below the center line of the wheel, to prevent accidental jamming of work between tool rest and wheel.

Wear goggles, even if eye shields are attached to the grinder. Keep your thumbs and fingers out of the wheel.

CUT-OFF SAW

The cut-off saw is a circular saw that is mounted on a radial arm. This arrangement is sometimes called a RADIAL ARM SAW. This machine is comparatively easy to move and is generally found on any woodworking job where there is quite a bit of sawing to do. The cut-off saw was primarily designed to cut boards off square but because of its versatility it can be used for ripping, cutting on an angle, dadoing, and many other wood cutting operations.

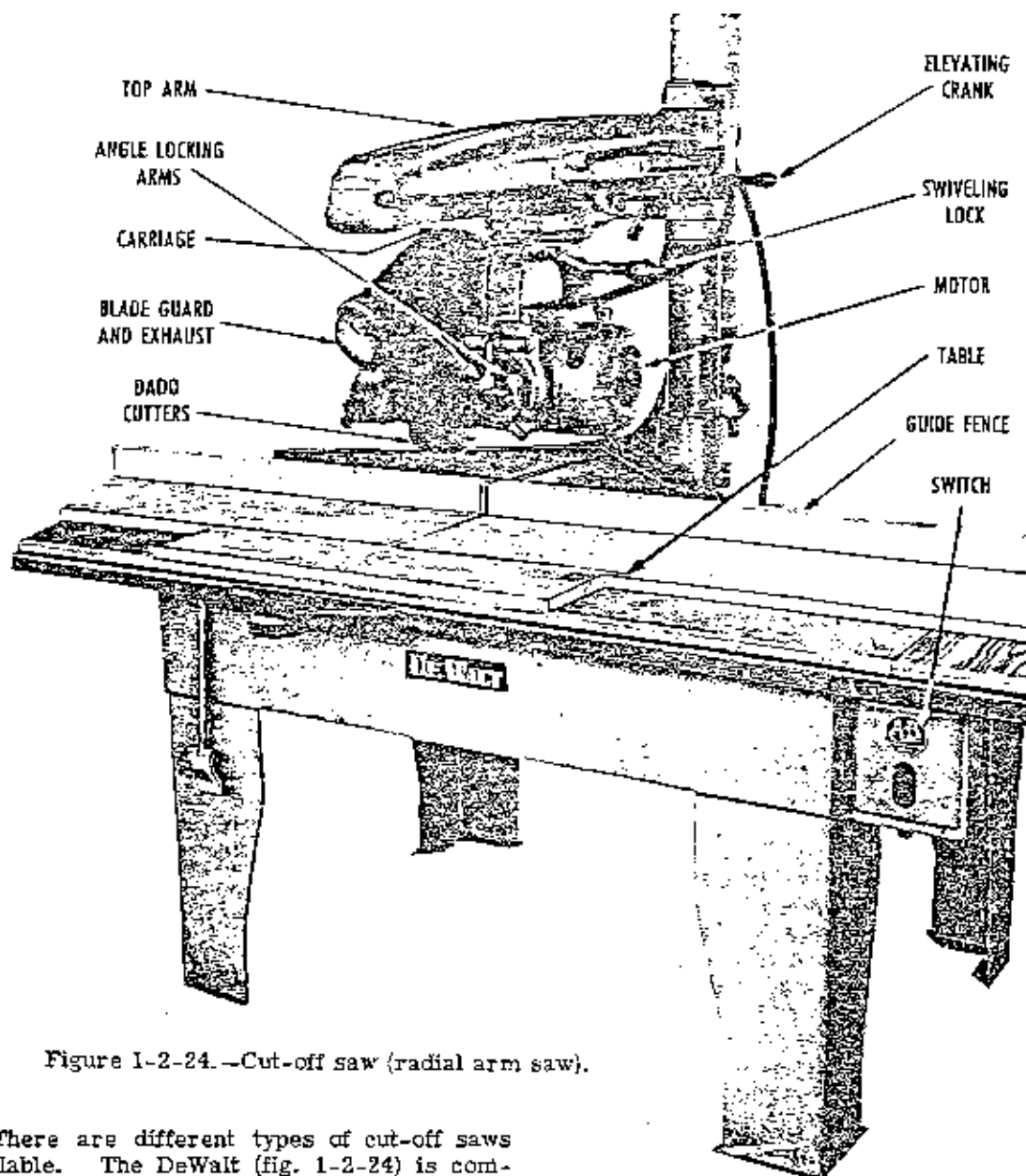


Figure 1-2-24.—Cut-off saw (radial arm saw).

There are different types of cut-off saws available. The DeWalt (fig. 1-2-24) is commonly used and is representative of what a cut-off saw is generally pictured to be. Its motor is incased in a yoke which is carried to travel to and fro in an overhead arm. The arm turns on a rigid column and can be adjusted up or down. Since the motor, too, can be turned and tilted, the whole relationship of components affords a flexibility of movement that will take care of nearly all wood-working operations.

Some of the latest models of cut-off saws have a built-in variable speed changer so you can select a suitable speed for the job being done. Some of them have an automatic brake so the saw blade stops in a few seconds when the switch is turned off.

Before you operate a radial arm saw, clean all dust and dirt from the blade, arbor face, and collar. The normal position of the blade is for the straight cut-off, where the blade is pulled from the rear to the front across the wood. The wood is placed on the table top with one side resting against the guide strip.

For other operations where the cut is greater than that permitted in crosscutting, the wood is placed flat on the table against the guide and is moved by hand to the blade.

The arm may be pushed at any desired angle for angle cutting. For ripping and ploughing, the blade may be pulled out to the end of the arm and locked in position between the guide strip and the motor. In this operation, the wood is pushed along the guide strip from the side opposite the guard into the blade. For beveling, shaping, and routing, the motor may be tilted and locked at any angle.

The most important operating precautions for the cut-off saw are:

1. The electrical current being used should agree exactly with the specifications on the motor.
2. All clamp handles should be properly tightened before you operate the machine.
3. Before starting to cut, be sure that the wood rests against the guide strip in the cut-off position.

4. Before changing any setup, stop the saw.
5. For all operations, adjust the blade guard down to the material.

Periodical cleaning, greasing, and oiling of all moving parts are necessary. This should be done in accordance with the manufacturer's manual and is generally controlled by the petty officer in charge of the shop in which the saw is installed. Each morning before starting operations with the cut-off saw, you should clean the tracks inside the arm by wiping. Occasionally, clean these tracks with an approved cleaning fluid to remove grease and dirt.

FASTENING DEVICES

Fastening devices are not tools; however, you will be using tools to install and remove them on any job that requires assembly or disassembly of equipment or structures.

Fastening devices, such as bolts, nuts, screws, and nails should be known by their names, sizes, and shapes. They are usually kept in storerooms or tool cribs and are issued when needed. When getting a fastener, you should know what you want so you can get the correct item in a minimum of time.

WOODWORKING FASTENERS

Before the development of nail-making, screw-making, and bolt-making machines, wooden members were held together by various types of interlocking joints that were reinforced with glue and wooden dowels. A dowel is a cylindrical hardwood pin which is driven into a hole bored to receive it, and which serves much the same purpose as a nail. Glued joints and joints fastened with wooden dowels are now confined mainly to furniture. Metal dowels are still used to fasten joints in window sashes, door members, and the like.

NAILS

Figure 1-3-1 shows the more common types of wire nails. The **BRAD** and the **FINISH NAIL** both have a **DEEP COUNTERSINK** head that is designed to be "set" below the surface of the work. The **CASING** nail has a **FLAT COUNTERSINK** head, which may be driven flush and left that way or which may also be "set." The other nails shown are all **FLAT-HEADED** nails. The **COMMON** nail is the one most widely used in general wood construction. Nails with **LARGE FLAT** heads are used for nailing roofing paper, plaster board, and similar thin or soft materials. **DUPLEX** or **DOUBLE-HEADED NAILS** are used for nailing temporary structures, such as scaffolds, which are eventually to be dismantled. A duplex nail has an upper and lower head. The

nail is driven to the lower head; it can be easily drawn by setting the claw of a hammer under the upper head.

Besides nails with the usual type of shank (round) there are various more or less special-purpose nails with shanks of other types. Nails

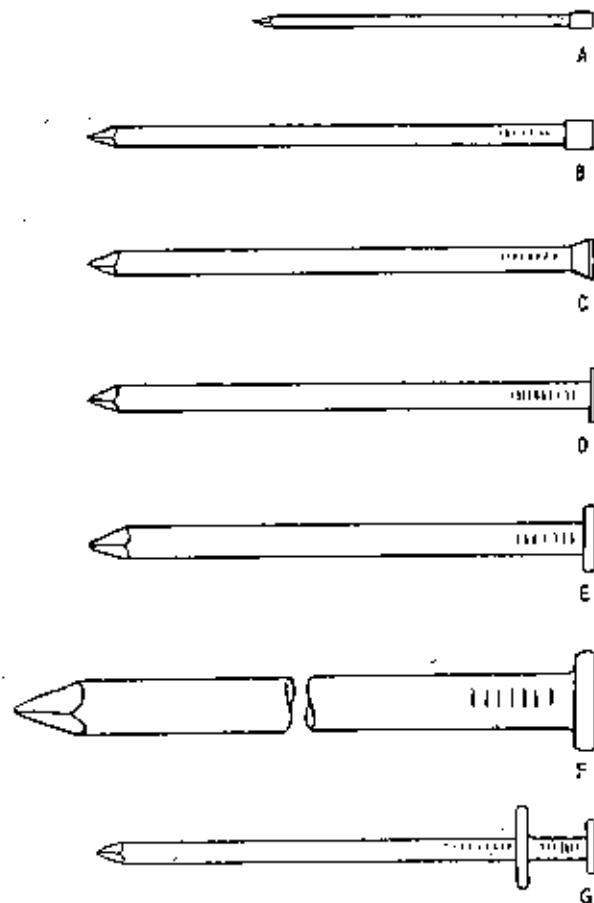


Figure 1-3-1.—(A) Brad, (B) Finish nail, (C) Casing nail, (D) Box nail, (E) Common nail, (F) Spike (larger than 60d), (G) Duplex head nail.

with **SQUARE**, **TRIANGULAR**, **LONGITUDINALLY GROOVED**, and **SPIRALLY GROOVED** shanks have a much greater holding power than wire nails of the same size. **CONCRETE** and **MASONRY** nails, designed to be driven into concrete or masonry, are hardened-steel nails which sometimes have longitudinally grooved shanks. A spirally grooved nail is called a **SCREW** nail.

The lengths of the most commonly used nails are designated by the **PENNY** system. This system originated in England, where the abbreviation for the word "penny" is the letter d (from **DENARIUS**, the Latin name of a Roman coin). Thus, the expression "a 2d nail" means "a two-penny nail." The thickness of a nail increases with the penny size and the number of nails per pound decreases. A box or casing nail of the same common nail penny size is thinner, and it takes more of them to weigh the same amount.

The penny sizes and corresponding length, thicknesses (in gage sizes) and numbers per pound of the most commonly used nails are shown in figure 1-3-2.

Nails larger than 60d (which are called spikes), and nails smaller than 2d are designated by their lengths in inches or in fractions of an inch.

WOOD SCREWS

Wood screws are designated as to types by the type of head (fig. 1-3-3) and material, as "flathead brass," "roundhead steel or blue" and so on. Most wood screws are made of either steel or brass, but there are copper and bronze wood screws as well. To distinguish the ordinary type of head from the Phillips head, the former is called a SLOTTED head. A LAG screw is a heavy iron screw with a square bolt-type head; lag screws are used mainly for fastening heavy timbers.

The size of an ordinary wood screw is designated by the length and the BODY DIAMETER (unthreaded part) of the screw. Body diameters are designated by GAGE NUMBERS running from 0 (for about a 1/16-in. diameter) to 24 (for about a 3/8-in. diameter). Lengths range from 1/4 in. to 5 in. The length and gage number are printed on the box, as "1 1/4-9." This means a No. 9 gage screw 1 1/4-inches long. Note that for a nail, a large gage number means a small nail; but for a screw, a large gage number means a large screw.

BOLTS

A BOLT is distinguished from a wood screw by the fact that it does not thread into the wood, but goes through and is held by a NUT threaded onto the end of the bolt. Figure 1-3-4 shows the four common types of bolts used in woodworking. STOVE bolts are rather small, ranging in length from 3/8 in. to 4 in., and in body diameter from 1/8 in. to 3/8 in. CARRIAGE AND MACHINE bolts run from 3/4 in. to 20 in. long, and from 3/16 in. to 3/4 in. in diameter. The carriage bolt has a square section below the head, which is imbedded in the wood to prevent turning as the nut is drawn up. The machine bolt has a square head which is held with a wrench to prevent it from turning.

METAL FASTENING DEVICES

Many mechanisms and devices are held together with metal fasteners. Only the more commonly used fasteners will be discussed here so you will know when, where and how they should be used. If a flat point setscrew was used where specifications called for a cone point an important installation might fail at a crucial moment.

Metal parts can be fastened together with various fastening devices, such as rivets, bolts, screws, etc. Rivets and riveting are explained in another section. Bolts and screws are made in many shapes and sizes. Only the more common ones will be discussed in this course. ROUGH and SEMIFINISHED bolts and screws are pressed, hammered, or punched out of cold or hot metal. FINISHED bolts and screws are cut out of a bar of steel by machine.

Bolts and screws are used to fasten together parts that may have to be taken apart later. A bolt is used where you can get at both sides of the work with wrenches. A screw is used where only one side can be reached with a wrench or screwdriver.

STANDARDIZED

At one time each manufacturer made as many threads per inch on bolts, screws, and nuts as suited his own particular needs. For example, one made 12 threads per inch on 1/2" bolts while another might put on 13 or 15 threads per inch. Thus the bolts of one manufacturer would not fit the nuts made by another. The NATIONAL SCREW THREAD COMMISSION was established to study this problem and suggest a solution. This committee decided to standardize on a two-thread series, one called the NATIONAL COARSE THREAD SERIES (NC) and the other the NATIONAL FINE THREAD SERIES (NF). The SOCIETY OF AUTOMOTIVE ENGINEERS decided to standardize on some EXTRA FINE (EF) threads to be used in airplanes, automobiles, and other places where extra fine threads are needed. Figure 1-3-5 shows the number of threads per inch for NC, NF, and EF thread sizes up to 1 inch in diameter.

There have been four classes of fits established by the National Screw Thread Commission. They are: Class I, loose fit; Class II, free fit; Class III, medium fit; and Class IV, close fit.

The loose fit is for threaded parts that can be put together quickly and easily even when the threads are slightly bruised or dirty, and when a considerable amount of shake or looseness is not objectionable. The free fit is for threaded parts that are to be put together nearly or entirely with the fingers and a little shake or looseness is not objectionable. This includes most of the screw thread work. The medium fit is for the higher grade of threaded parts. It is the same as free fit, except that the fit is somewhat closer. The close fit is for the finest threaded work where very little shake or looseness is desirable and where a screwdriver or wrench may be necessary to put the parts together. The manufacture of threaded parts belonging to this class requires the use of fine tools and gages. This fit should, therefore, be used only where requirements are exacting or where special conditions require screws having a fine, snug fit.

COMMON WIRE NAILS

Size	Length	Gage	Approx. No. to Lb.	Size	Length	Gage	Approx. No. to Lb.
2D	1 In.	No. 15	876	10D	3 In.	No. 9	69
3D	1-1/4	14	568	12D	3-1/4	8	63
4D	1-1/2	12-1/2	316	16D	3-1/2	8	49
5D	1-3/4	12-1/2	271	20D	4	6	31
6D	2	11-1/2	181	30D	4-1/2	5	24
7D	2-1/4	11-1/2	161	40D	5	4	18
8D	2-1/2	10-1/4	106	50D	5-1/2	3	14
9D	2-3/4	10-1/4	96	60D	6	2	11

FLOORING BRADS

Size	Length	Gage	Approx. No. to Lb.
6D	2 In.	No. 11	157
7D	2-1/4	11	139
8D	2-1/2	10	99
9D	2-3/4	10	90
10D	3	9	69
12D	3-1/4	8	54
16D	3-1/2	7	43
20D	4	6	31

FINISHING NAILS

Size	Length	Gage	Approx. No. to Lb.
2D	1 In.	No. 16-1/2	1351
3D	1-1/4	15-1/2	807
4D	1-1/2	15	584
5D	1-3/4	15	500
6D	2	13	309
7D	2-1/4	13	238
8D	2-1/2	12-1/2	189
9D	2-3/4	12-1/2	172
10D	3	11-1/2	121
12D	3-1/4	11-1/2	113
16D	3-1/2	11	90
20D	4	10	62

CASING NAILS

Size	Length	Gage	Approx. No. to Lb.
2D	1 In.	No. 15-1/2	1010
3D	1-1/4	14-1/2	635
4D	1-1/2	14	473
5D	1-3/4	14	406
6D	2	12-1/2	236
7D	2-1/4	12-1/2	210
8D	2-1/2	11-1/2	145
9D	2-3/4	11-1/2	132
10D	3	10-1/2	94
12D	3-1/4	10-1/2	87
16D	3-1/2	10	71
20D	4	9	52
30D	4-1/2	9	46

SMOOTH & BARBED BOX NAILS

Size	Length	Gage	Approx. No. to Lb.
2D	1 In.	No. 15-1/2	1010
3D	1-1/4	14-1/2	635
4D	1-1/2	14	473
5D	1-3/4	14	406
6D	2	12-1/2	236
7D	2-1/4	12-1/2	210
8D	2-1/2	11-1/2	145
9D	2-3/4	11-1/2	132
10D	3	10-1/2	94
12D	3-1/4	10-1/2	88
16D	3-1/2	10	71
20D	4	9	52
30D	4-1/2	9	46
40D	5	8	35

Figure 1-3-2.—Sizes of most commonly used nails.

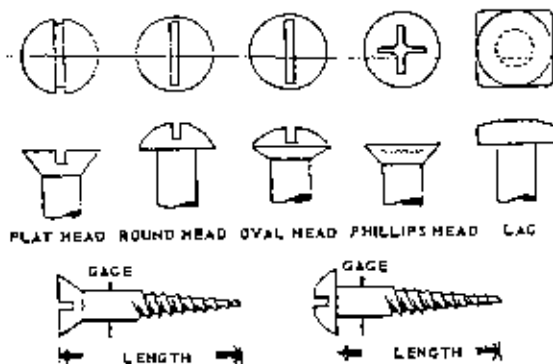


Figure 1-3-3.—Common types of wood screws.

MACHINE SCREWS

The term "machine screw" is the general term used to designate small screws used in tapped holes for the assembly of metal parts. Machine screws may be used with nuts, but usually they are screwed into holes that have been tapped with matching threads.

Most machine screws are made of steel or brass. They may be plated to help prevent corrosion. Special machine screws made of aluminum or stainless steel are obtainable; the latter are very strong and highly resistant to the corrosive action of salt water.

A great variety of diameters, lengths, and head shapes are manufactured. The complete description of machine screws must include the LENGTH in inches, THREAD-DIAMETER, HEAD SHAPE, MATERIAL from which made,

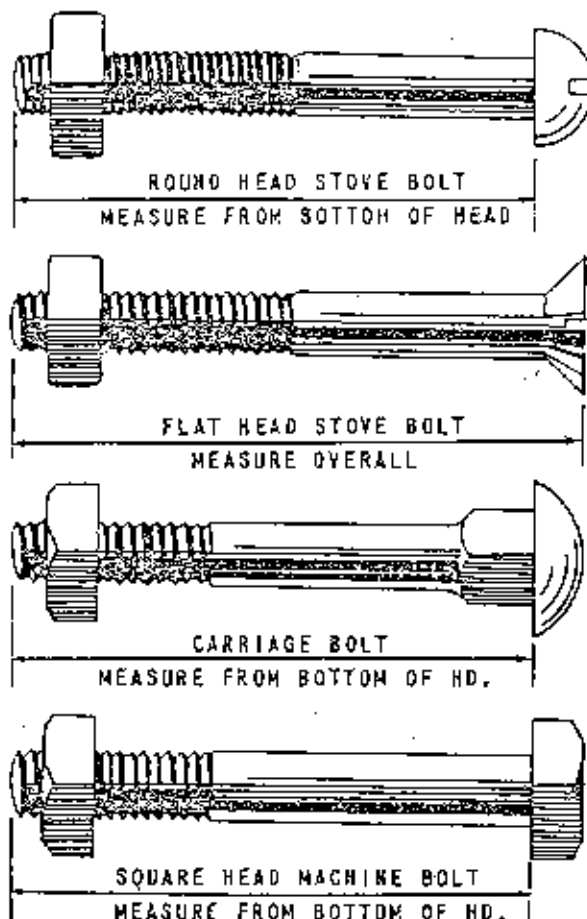


Figure 1-3-4.—Common types of bolts.

Diameter		Threads Per Inch			
No.	Inch	Decimal Equivalent	NC	NF	EF
0	---	.0600	---	80	---
1	---	.0730	64	72	---
2	---	.0860	56	64	---
3	---	.0990	48	56	---
4	---	.1120	40	48	---
5	---	.1250	40	44	---
6	---	.1380	32	40	---
8	---	.1640	32	36	---
10	---	.1900	24	32	40
12	---	.2160	24	28	---
---	1/4	.2500	20	28	36
---	5/16	.3125	18	24	32
---	3/8	.3750	16	24	32
---	7/16	.4375	14	20	28
---	1/2	.5000	13	20	28
---	9/16	.5625	12	18	24
---	5/8	.6250	11	18	24
---	3/4	.7500	10	16	20
---	7/8	.8750	9	14	20
---	1	1.0000	8	14	20

Figure 1-3-5.—Screw threads per inch.

and FINISH. Here is a typical example—"1/2 inch, 8-32, round head, brass, chromium plated, machine screw." The "8-32" means that the screw gage is No. 8 and that it has 32 threads per inch.

Machine screws are driven with a screw-driver or wrench, depending on the type of screw head.

Holes for FILLISTER-HEAD machine screws must be counterbored so that the heads will be flush with or below the surface.

Most of the time you will use the common types of machine screws shown in figure 1-3-6, but you may have occasion to use some of the special types shown in figure 1-3-7. Note that some of these special machine screws require special tools for driving and removing. These tools are usually included in a kit that comes with the machine or installation on which the screws are used.

Nuts are seldom used on machine screws, but square or hex nuts may be. When a nut is needed, make sure the threads of the bolt and nut are the same gage and pitch.

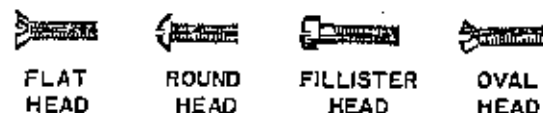


Figure 1-3-6.—Common types of machine screws.

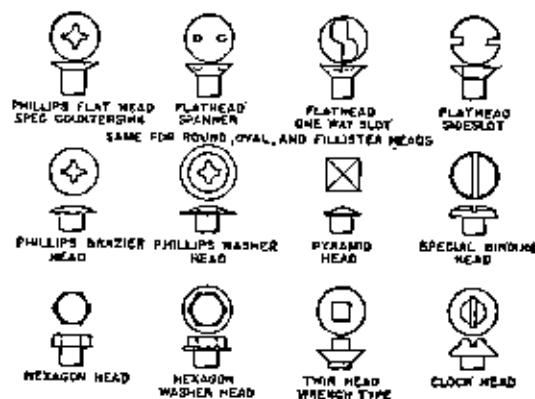


Figure 1-3-7.—Special machine screws.

CAPSCREWS

Capscrews (fig. 1-3-8) are usually used without nuts, to hold parts of machines and engines together. They are screwed into tapped holes, and are sometimes referred to as tap bolts. Threads may be either NF or NC. Capscrews perform the same functions as machine screws, but come in larger sizes for heavier work. Sizes range up to 1 inch in diameter and 6 inches in length.

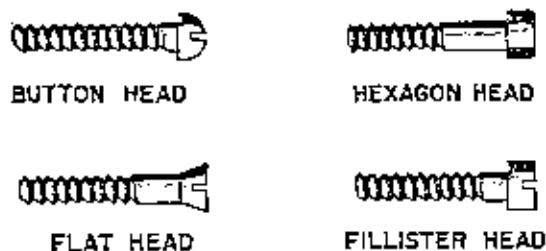


Figure 1-3-8.—Capscrews.

Capscrews may have square, hex, flat, button, or fillister heads. Fillister heads are best for use on moving parts because such heads are sunk into counterbored holes. Hex heads are usually used where the metal parts do not move.

The strongest capscrews are made of alloy steel, and can withstand great stresses, strains, and shearing forces. Capscrews made of stainless steel are often specified on machinery that is exposed to salt water.

Some capscrews have small holes through their heads. A wire, called a SAFETY WIRE, is run through the holes of several capscrews to keep them from coming loose.

STUDS

Studs might be called headless bolts. Both ends are threaded, one to screw into a tapped hole and the other to take a nut. (See fig. 1-3-9.)



Figure 1-3-9.—Studs.

One important use of studs is to hold down the cylinder heads of boat and automobile engines. An important advantage of a stud over a bolt is that the nut can still be removed, even if the end screwed into the casting is "frozen". The end of the stud that screws into the casting usually has NC threads.

SETSCREWS

Set screws are used to secure small pulleys, gears, and cams to shafts, and to provide positive adjustment of machine parts. They are classified by diameter, thread, head shape, and point shape. The point shape is important because it determines the holding qualities of the setscrew.

Set screws hold best if they have either a CONE POINT or a DOG POINT, shown in figure 1-3-10. These points fit into matching recesses in the shaft against which they bear.

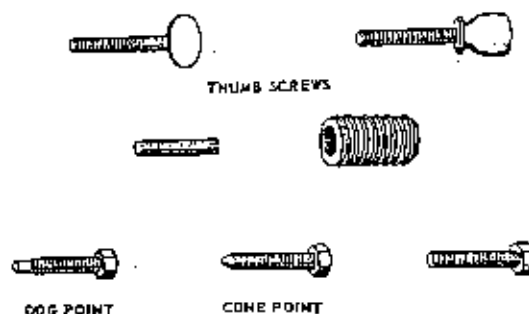


Figure 1-3-10.—Set screws and thumb screws.

HEADLESS SETSCREWS—slotted, Allen or Bristo types—are used with moving parts because they do not stick up above the surface. They are threaded all the way from point to head. **COMMON SETSCREWS**, used on fixed parts, have square heads. They have threads all the way from the point to the shoulder of the head.

THUMB SCREWS are used for set screws, adjusting screws, and clamping screws. Because of their design they can be loosened or tightened without the use of tools.

NUTS

SQUARE and **HEXAGONAL** nuts are standard but they are supplemented by special nuts. (See fig. 1-3-11.) One of these is the **JAM NUT**, used above a standard hex nut to lock it in position. It

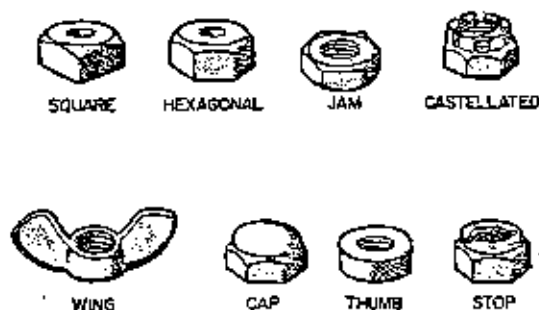


Figure 1-3-11.—Common kinds of nuts.

is about half as thick as the standard hex nut, and has a washer face.

CASTELLATED nuts are slotted so that a **COTTER KEY** may be pushed through the slots matching a hole in the bolt. This provides a positive method of preventing the nut from working loose. For example, you will see these nuts used with the bolts that hold the two halves of an engine connecting rod together. They are usually used with machine bolts.

WING NUTS are used where frequent adjustment is required. **CAP**, or **ACORN** nuts, are used where appearance is an important consideration. They are usually made of chromium plated brass. **THUMB NUTS** are knurled, so they can be turned by hand for easy assembly and disassembly.

ELASTIC STOP NUTS are used where it is imperative that the nut does not come loose. These nuts have a fiber or composition washer built into them which is compressed automatically against the screw threads to provide holding tension. They are used extensively on radio, sound equipment, fire control equipment and on aircraft.

WASHERS

Figure 1-3-12 shows the types of washers most used.

FLAT WASHERS are used to back up bolt heads and nuts, and to provide larger bearing surfaces. They also prevent damage to the surfaces of the metal parts through which a bolt passes.

SPLIT LOCK WASHERS are used under nuts to prevent loosening by vibration. The ends of these spring-hardened washers dig into both the nut and the work to prevent slippage.

SHAKEPROOF LOCK WASHERS have teeth or lugs that grip both the work and the nut. Several patented designs, shapes, and sizes are obtainable.



Figure 1-3-12.—Washers.

KEYS AND PINS

COTTER KEYS (fig. 1-3-13) are used to secure castellated nuts on bolts and rods. They are also used as stops and holders on shafts and rods. **SQUARE KEYS** and **WOODRUFF KEYS** are used to prevent hand wheels, gears, cams and pulleys from turning on a shaft. These keys are strong enough to carry heavy loads if they are fitted and seated properly.

TAPER PINS are used to locate and position matching parts. They are also used to secure small pulleys and gears to shafts. They usually have a taper of 1/4-inch per foot. Holes for taper pins must be reamed with tapered reamers so they will fit properly.

DOWEL PINS are used to position and align the units or parts of an assembly. They are used in assemblies that must be frequently disassembled and assembled. One end of a dowel pin is chamfered, and it is usually .001 to .002 inch greater in diameter than the specified size. This allows the hole for the pin to be reamed to ensure a close fit.

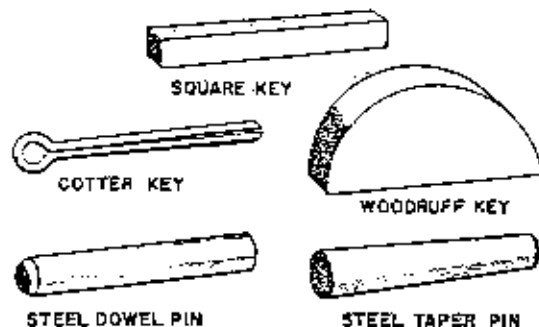


Figure 1-3-13.—Keys and pins.

MEASURING

The ability to measure with any degree of accuracy depends upon the correct use of measuring tools.

TAKING A MEASUREMENT WITH A COMMON RULE

To take a measurement with a common rule, hold the rule with its edge on the surface of the object being measured. This will eliminate errors which might result due to the thickness of the rule. Except in tapes, this thickness causes the graduations to be a slight distance away from the surface of the object. Read the measurement at the graduation which coincides with the distance to be measured, and state it as being so many inches and fractions of an inch. (See fig. 2-1-1.) Always reduce fractions to their lowest terms, for example, 6/8 inch would be called 3/4 inch.

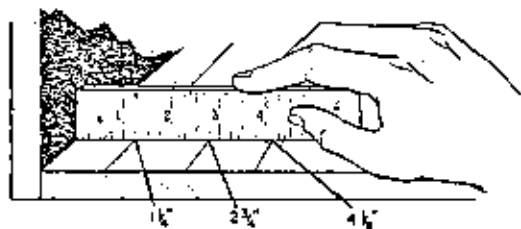


Figure 2-1-1.—Measuring with and reading a common rule

MEASURING THE LENGTH OF A BOLT OR SCREW

The length of bolts and screws is best measured by holding them up against a rigid rule or tape. Hold both the bolt or screw to be measured and the rule up to your eye level so that your line of sight will not be in error in reading the measurement. As shown in figure 2-1-2, the bolts or screws with countersink type heads are measured from the top of the head to the opposite end, while those with other type heads are measured from the bottom of the head.

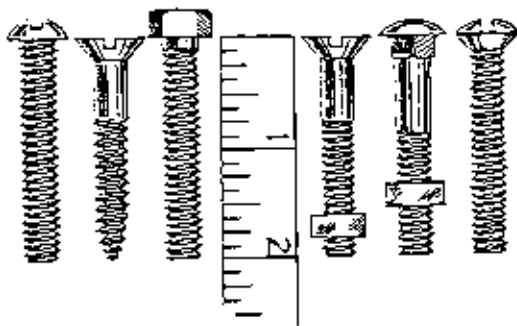


Figure 2-1-2.—Measuring the length of a bolt or screw.

MEASURING THE OUTSIDE DIAMETER OF A PIPE

To measure the outside diameter of a pipe, it is best to use some kind of rigid rule. A folding wooden rule or a steel rule is satisfactory for this purpose. As shown in figure 2-1-3, line up the end of the rule with one side of the pipe, using your thumb as a stop. Then with the other end held in place with your thumb, swing the rule through an arc and take the maximum reading at the other side of the pipe. For most practical purposes, the measurement obtained by using this method is satisfactory. It is necessary that you know how to take this measurement as the outside diameter of pipe is the only dimension given on pipe specifications.

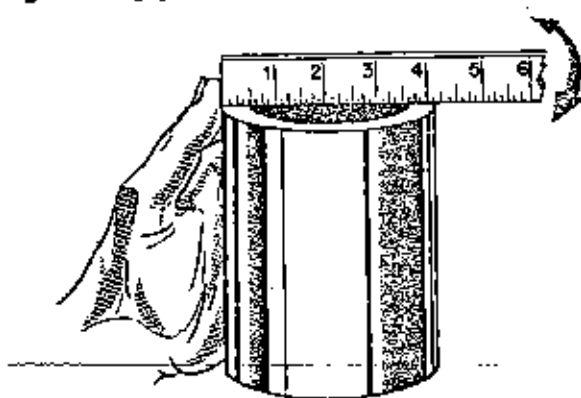


Figure 2-1-3.—Measuring the outside diameter of a pipe.

MEASURING INSIDE DIAMETER OF PIPE WITH A RULE

To measure the inside diameter of a pipe with a rule, as shown in figure 2-1-4, hold the rule so that one corner of the rule just rests on the inside of one side of the pipe. Then, with one end thus held in place, swing the rule through an arc and read the diameter across the maximum inside distance. This method is satisfactory for an approximate inside measurement.

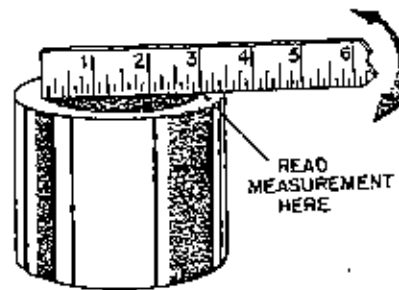


Figure 2-1-4.—Measuring the inside diameter of a pipe.

MEASURING THE CIRCUMFERENCE OF A PIPE

To measure the circumference of a pipe, a flexible type rule that will conform to the cylindrical shape of the pipe must be used. A web tape rule or a steel tape is adaptable for this job. When measuring pipe, make sure the tape has been wrapped squarely around the axis of the pipe (i.e., measurement should be taken in a plane perpendicular to the axis) to ensure that the reading will not be more than the actual circumference of the pipe. This is extremely important when measuring large diameter pipe.

Hold the rule or tape as shown in figure 2-1-5. Take the reading, using the 2-inch graduation, for example, as the reference point. In this case the correct reading is found by subtracting 2 inches from the actual reading. In this way the first 2 inches of the tape, serving as a handle, will enable you to hold the tape securely.

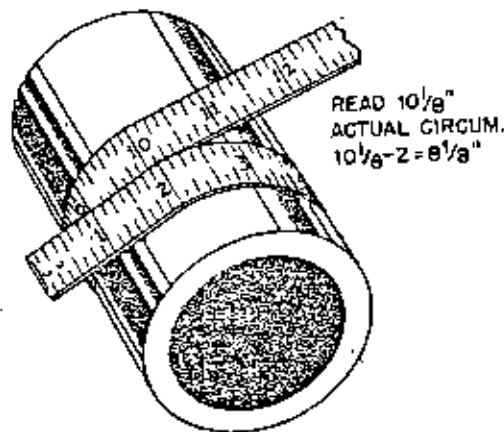


Figure 2-1-5.—Measuring the circumference of a pipe with a tape

MEASURING AN INSIDE DIMENSION USING A FOLDING RULE

To take an inside measurement, such as the inside of a box, a folding rule that incorporates a 6- or 7-inch sliding extension is one of the best measuring tools for this job. To take the inside measurement, first unfold the folding rule to the

approximate dimension. Then extend the end of the rule and read the length that it extends, adding the length of the extension to the length on the main body of the rule. (See fig. 2-1-6.) In this illustration the length of the main body of the rule is 13 inches and the extension is pulled out $3 \frac{3}{16}$ inches. In this case the total inside dimension being measured is $16 \frac{3}{16}$ inches.

MEASURING AN INSIDE DIMENSION USING A TAPE RULE

In figure 2-1-7 notice in the circle that the hook at the end of the particular rule shown is

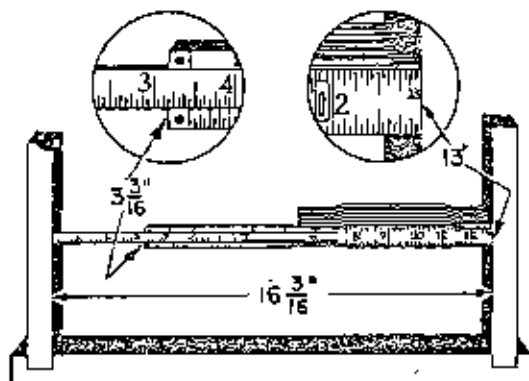


Figure 2-1-6.—Using a folding rule to measure an inside dimension.

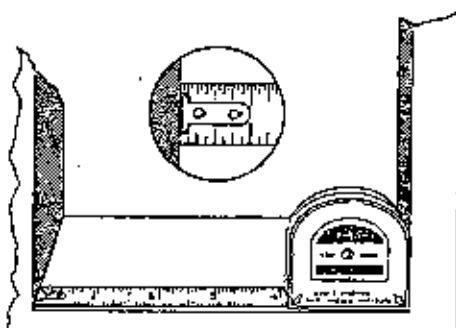


Figure 2-1-7.—Measuring an inside dimension with a tape rule.

attached so that it is free to move slightly. When an outside dimension is taken by hooking the end of the rule over an edge, the hook will locate the end of the rule even with the surface from which the measurement is being taken. By being free to move, the hook will retract away from the end of the rule when an inside dimension is taken. To measure an inside dimension using a tape rule, extend the rule between the surfaces as shown, take a reading at the point on the scale where the rule enters the case, and add 2 inches. The 2 inches are the width of the case. The total is the inside dimension being taken.

MEASURING AN OUTSIDE DIMENSION USING A TAPE RULE

To measure an outside dimension using a tape rule, hook the rule over the edge of the stock. Pull the tape out until it projects far enough from the case to permit measuring the required distance. The hook at the end of the rule is designed so that it will locate the end of the rule at the surface from which the measurement is being taken. (See fig. 2-1-8.) When taking a measurement of length, the tape is held parallel to the lengthwise edge. For measuring widths, the tape should be at right angles to the lengthwise edge. Read the dimension of the rule exactly at the edge of the piece being measured.

It may not always be possible to hook the end of the tape over the edge of stock being measured. In this case it may be necessary to butt the end of the tape against another surface or to hold the rule at a starting point from which a measurement is to be taken.

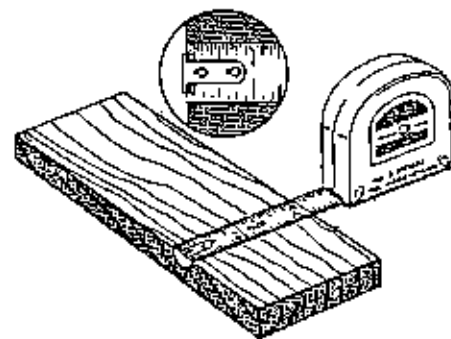


Figure 2-1-8.—Measuring an outside dimension using a tape rule.

HOW TO USE A STEEL TAPE OR WEB TAPE

Steel or web tapes are generally used for making long measurements. Secure the hook end of the tape to the outside edge, or corner, or end of the object to be measured. Hold the tape reel in the hand and allow it to unwind while walking in the direction in which the measurement is to be taken. Stretch the tape with sufficient tension to overcome sagging. At the same time make sure the tape is parallel to an edge or the surface being measured. Read the graduation on the tape by noting which line on the tape coincides with the measurement being taken.

MEASURING THE THICKNESS OF STOCK THROUGH A HOLE

To measure the thickness of stock through a hole with a hook rule, insert the rule through the hole, hold the hook against one face of the stock, and read the thickness at the other face. (See fig. 2-1-9.)

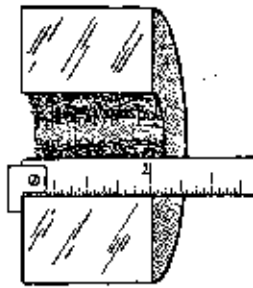


Figure 2-1-9.—Measuring the thickness of stock through a hole.

USING CALIPERS

A caliper is usually used in one of two ways. Either the caliper is set to the dimension of the work and the dimension transferred to a scale or the caliper is set on a scale and the work machined until it checks with the dimension set up on the caliper. To adjust a caliper to a scale dimension, one leg of the caliper should be held firmly against one end of the scale and the other leg adjusted to the desired dimension. To adjust a caliper to the work, open the legs wider than the work and then bring them down to the work. A sense of "feel" must be acquired to use calipers properly. This comes through practice and care in using the tool to eliminate the possibility of error. Always position the caliper properly on the axis of the work.

NOTE: Never set a caliper on work that is revolving in a machine.

The contact of one leg of a caliper on a revolving surface will tend to draw the other leg over the work because of the friction between the moving surfaces. Only a slight force is necessary to spring the legs of a caliper so that other measurements made with it are never accurate.

MEASURING THE DIAMETER OF ROUND STOCK OR THE THICKNESS OF FLAT STOCK USING AN OUTSIDE CALIPER

To measure the diameter of round stock, or the thickness of flat stock, adjust the outside caliper so that you feel a slight drag as you pass it over the stock. (See fig. 2-1-10.) After the proper "feel" has been attained, measure the setting of the caliper with a rule. Sight over the leg of the caliper after making sure the caliper is set squarely with the face of the rule.

MEASURING HARD TO REACH DIMENSIONS WITH A CALIPER

To caliper an almost inaccessible outside dimension such as the thickness of the bottom of a cup, use an outside transfer firm-joint caliper as shown in figure 2-1-11. When the proper "feel" is obtained, tighten the lock joint.

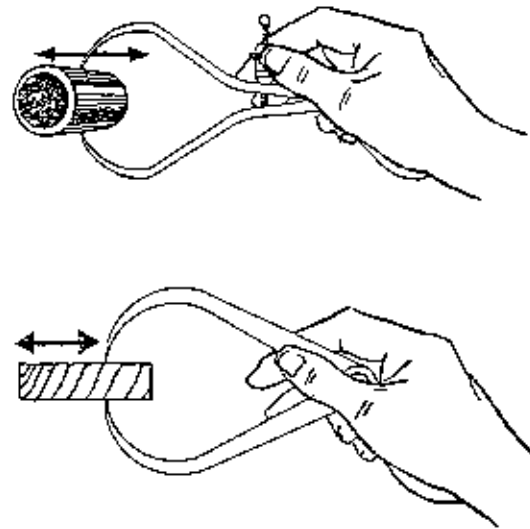


Figure 2-1-10.—Using an outside caliper.

Note that with the joint locked the auxiliary arm will remain in place. Loosen the binding nut and open the caliper enough to remove it from the cup. Close the caliper again and tighten the binding nut to seat in the slot at the end of the auxiliary arm. The caliper is now at the original setting, representing the thickness of the bottom of the cup. The caliper setting can now be measured with a rule.

To measure a hard to reach inside dimension, such as the internal groove shown in figure 2-1-12, a lock-joint inside caliper should be used. The procedure followed for measuring a hard to reach outside dimension is used.

MEASURING THE DISTANCE BETWEEN TWO SURFACES WITH AN INSIDE CALIPER

To measure the distance between two surfaces with an inside caliper, first set the caliper

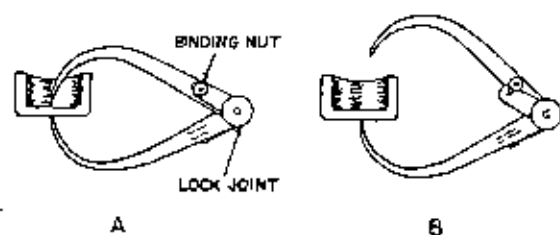


Figure 2-1-11.—Measuring the thickness of the bottom of a cup

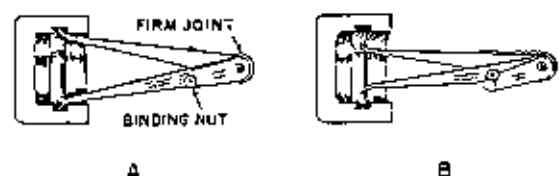


Figure 2-1-12.—Measuring a hard to reach inside dimension with an inside caliper.

to the approximate distance being measured. Hold the caliper with one leg in contact with one of the surfaces being measured. (See fig. 2-1-13.) Then as you increase the setting of the caliper, move the other leg from left to right. Feel for the slight drag indicating the proper setting of the caliper. Then measure the setting with a rule.

MEASURING THE DIAMETER OF A HOLE WITH AN INSIDE CALIPER

To measure the diameter of a hole with an inside caliper, hold the caliper with one leg in contact with one side of the hole (fig. 2-1-14) and, as you increase the setting, move the other leg from left to right and in and out of the hole. When you have found the point of largest diameter, measure the caliper setting with a rule.

MEASURING THE LENGTH OF A CURVE

To measure the length of a curve with dividers, step off the curve as you would step off a straight line. (See fig. 2-1-15.) First set the dividers to any small, even part of an inch. In setting a divider to a dimension on a scale,

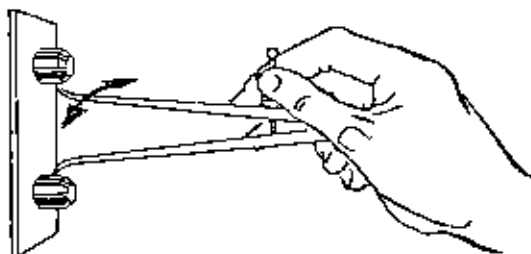


Figure 2-1-13.—Measuring the distance between two surfaces with an inside caliper.

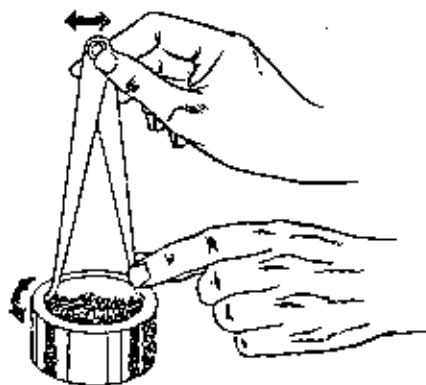


Figure 2-1-14.—Measuring an inside diameter with an inside caliper.

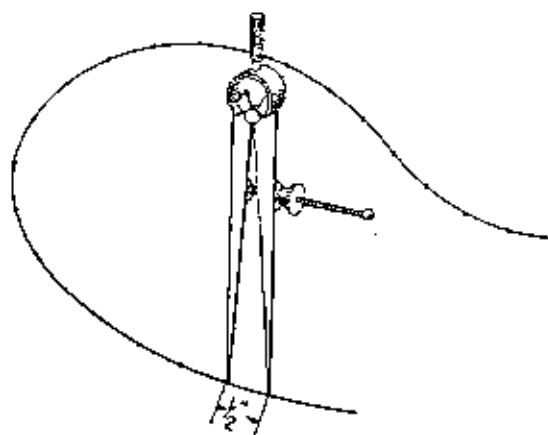


Figure 2-1-15.—Using a divider to measure the length of a curve.

the usual procedure is to locate one point in one of the inch graduations of the rule and to adjust the divider so that the other point falls easily into the correct graduation. Make certain the points of the divider are not blunt. Extreme care is necessary in this setting because any error will be a cumulative error which increases as the length of the curve being measured increases. Then step off the curve, counting the number of "steps." This number, multiplied by the setting of the divider, will be only the approximate length of the curve, because you are stepping off a straight-line distance along a curved line, and a straight line is the shortest distance between two points. Therefore, the actual distance, or the length of the curve, will be a little greater than your totaled measurements. The accuracy of the totaled measurements will increase as the setting on the divider decreases.

MEASURING INSIDE AND OUTSIDE DIAMETERS WITH POCKET SLIDE CALIPERS

To measure the outside diameter of round stock, or the thickness of flat stock, with a pocket slide caliper, move the jaws of the caliper into firm contact with the surface of the stock. Read the measurement at the reference line stamped OUT. (See fig. 2-1-16.)

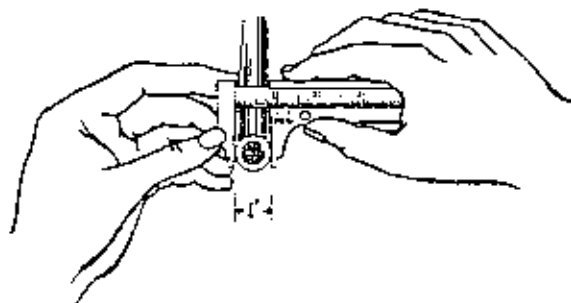


Figure 2-1-16.—Measuring an outside dimension with a pocket slide caliper.

To measure the inside diameter of a hole, or the distance between two surfaces, using a pocket slide caliper, insert only the rounded tips of the caliper jaws into the hole or between the two surfaces. (See fig. 2-1-17.) Read the measurement on the reference line stamped IN.

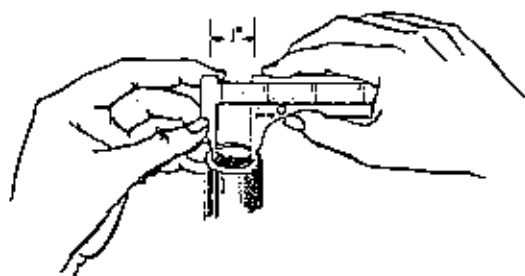


Figure 2-1-17.—Measuring an inside dimension with a slide caliper.

Note that two reference lines are needed if the caliper is to measure both outside and inside dimensions, and that they are separated by an amount equal to the outside dimension of the rounded tips when the caliper is closed.

MEASURING THE DEPTH OF A SLOT WITH A COMBINATION SQUARE

When using a combination square for measuring the depth of a slot, rest the squaring head on the surface of the work. (See fig. 2-1-18.) Loosen the blade friction screw and extend the blade to the bottom of the slot or shoulder, and retighten the screw to maintain the setting. Read the depth of the slot on the scale.

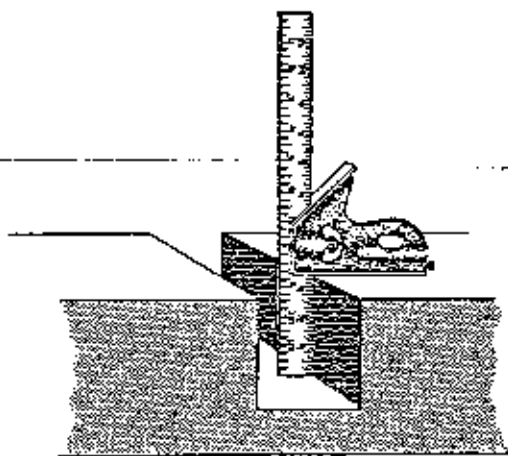


Figure 2-1-18.—Measuring the depth of a slot with a combination square.

MEASURING THE DEPTH OF A SLOT WITH A DEPTH GAGE

To measure the depth of a hole or slot with reasonable accuracy, use a depth gage as shown in figure 2-1-19 A. Hold the body of the depth gage against the surface from which the depth is to be measured and extend the scale into the hole or slot. Tighten the setscrew to maintain the setting. Withdraw the tool from the work and read the depth on the scale.

To measure the depth of a hole or slot with more accuracy than is possible with an ordinary depth gage, place a vernier depth gage over the slot as shown in figure 2-1-19 B. Notice the clamping screws are at X and Y; the horizontal adjusting screw nut is at Z. With X and Y loose, slide the scale down into the slot being measured until it is almost in contact. Then tighten X to make Z operative. With Z, adjust the scale to the "proper feel" and secure the setting with Y. By proper feel we mean the adjustment at which you first notice contact between the end of the scale and the bottom of the slot. Then read the setting as described under "Reading a vernier scale" in part I section 1 of this course.

To set the vernier depth gage to a particular setting, loosen both setscrews at X and at Y and slide the scale through the gage to the approximate setting. Tighten the setscrew at X, turn the knurled nut at Z until the desired setting is made, and tighten the setscrew at Y to hold the setting.

To measure the depth of a hole or slot, as shown in figure 2-1-19 C, with more accuracy than is possible with either an ordinary depth gage or a vernier depth gage, place a micrometer depth gage over the slot and adjust the thimble until the contact of the spindle causes

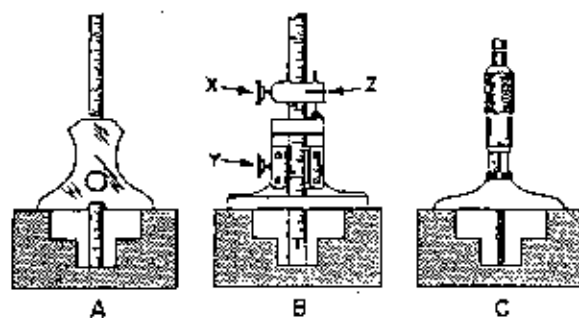
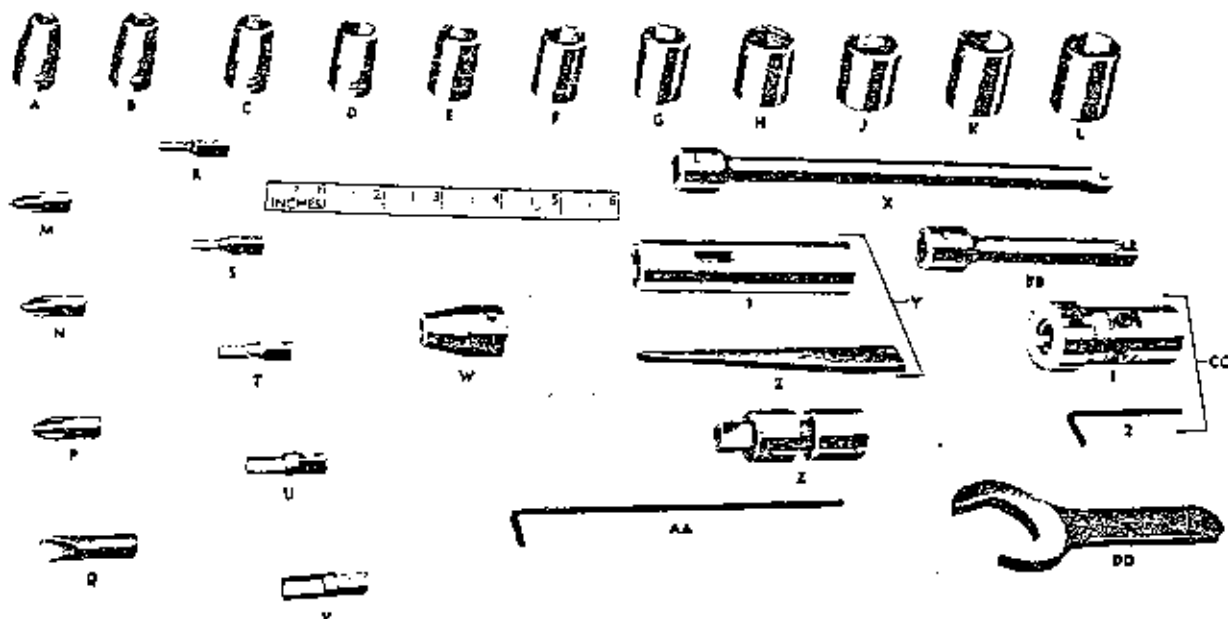


Figure 2-1-19.—Using depth gages.

the ratchet stop to slip. Remove the micrometer from the work and read the micrometer. Remember, if extension rods are used, the total depth reading will be the sum of the length of the rods plus the reading on the micrometer.



Heavy duty industrial type 6 point 1/2-inch, sq-drive (detachable socket wrenches

- | | | |
|-----------------|------------------|------------------|
| A 3/8-in. opng | E 5/8-in. opng | J 7/8-in. opng |
| B 7/16-in. opng | F 11/16-in. opng | K 15/16-in. opng |
| C 1/2-in. opng | G 3/4-in. opng | L 1-in. opng |
| D 9/16-in. opng | H 13/16-in. opng | |

Recessed screw (Phillips) screwdriver bits

- M No. 2 point 5/16-in. sq-shk
N No. 3 point 5/16-in. sq-shk
P No. 4 point 5/16-in. sq-shk

Hollow-head set or cap screw screwdriver bits

- R 3/16-in. hex 5/16-in. sq-shk
S 7/32-in. hex 5/16-in. sq-shk
T 1/4-in. hex 5/16-in. sq-shk
U 5/16-in. hex 5/16-in. sq-shk
V 3/8-in. hex 5/16-in. sq-shk
W 5/16-in. sq-opng 1/2-in. sq-drive bit holder
X 10-in. long 1/2-in. sq-drive hv-duty industrial type extn socket wrench bar
Y 1/2-in. sq-drive No. 2 Morse taper socket w/drift
1 1/2-in. sq-drive No. 2 Morse taper socket
2 Drill (for No. 2 Morse taper socket)
Z 1/2-in. sq-drive hv-duty industrial type univ socket wrench joint

- Q 5/16-in. blade 5/16-in. sq-shk slotted head screw screwdriver bit

- AA No. 10 and 12 cap screw 5/16-in set-screw 5/32-in. hex reg long arm series plug type hex (hollow-hd) set or cap screw wrench

- BB 5-in. long 1/2-in. sq-drive hv-duty industrial type extn socket wrench bar
CC 3/16 to 3/8-in. cap 1/2-in. sq-drive collet type chuck (for rd shank tools) w/wrenches

- 1 3/16 to 3/8-in. cap 1/2-in. sq-drive collet type chuck (for rd shank tools)
2 No. 10 and 12 cap screw 5/16-in. set screw 5/32-in. hex reg short arm series plug type hex (hollow-hd) set or cap screw wrench

- DD Size of opng 1-5/16-in. carb-s single open end angle 15° engrs wrench.

Figure 1-2-12--Equipment used with the electric impact wrench.

For proper operation, pneumatic drills require air pressure from 70 to 90 psi. Check the specifications on the drill you have and make sure you have the proper air pressure.

The air motor requires clean air and lubrication. Care should be taken to ensure clean couplings and air hose. In extremely dusty, humid, and cold regions, air compressor air filters and/or moisture traps are required to ensure that compressed air is dry and free from foreign matter. You should make sure that the air filters and moisture traps are cleaned periodically as suggested by the manufacturer's manual.

The only control required for operation of the pneumatic drill is the trigger (fig. 1-2-15). To start the drill the trigger is depressed. The drill is stopped by releasing the finger pressure on the trigger.

Before operating a pneumatic drill inspect the air hose and check for any leaks and damage. Be sure that an authorized lubricator is installed in the lead hose. Blow air through the air hose to free it of foreign material before connecting it to the

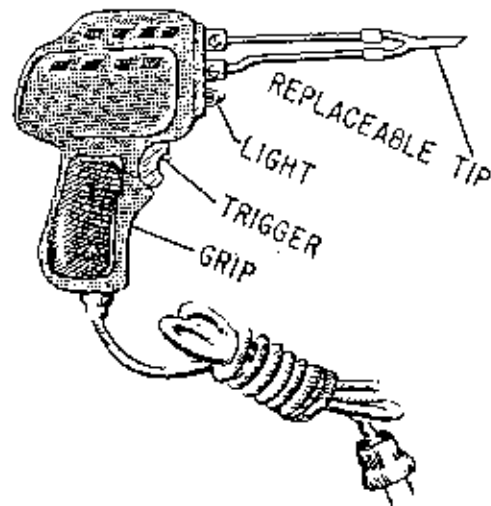


Figure 1-2-13.—Electric soldering gun.

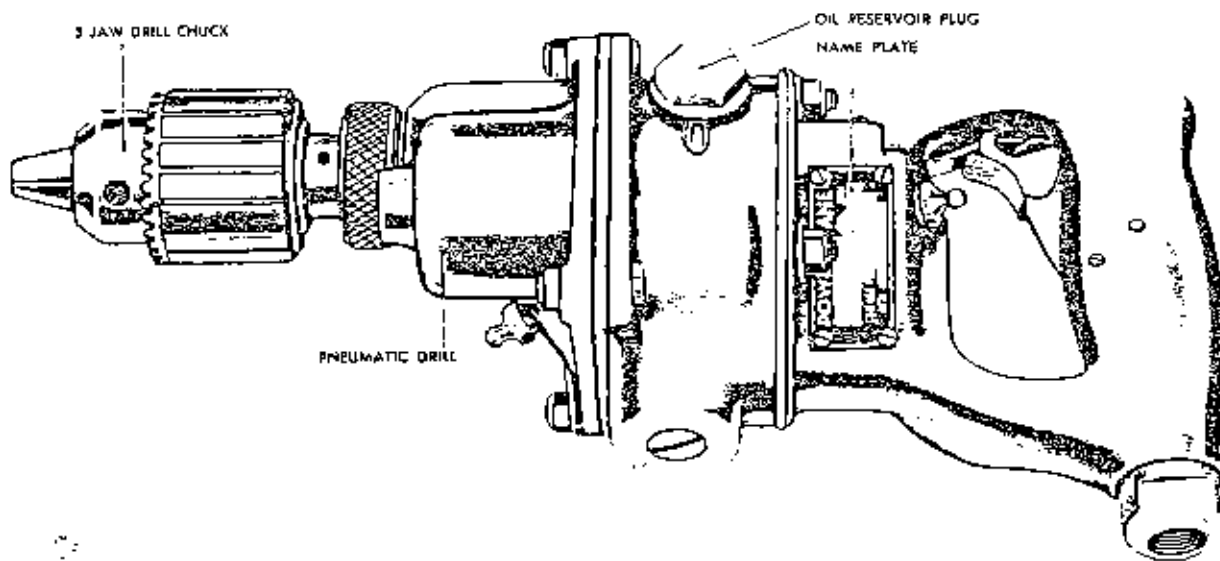


Figure 1-2-14.—Portable pneumatic drill.

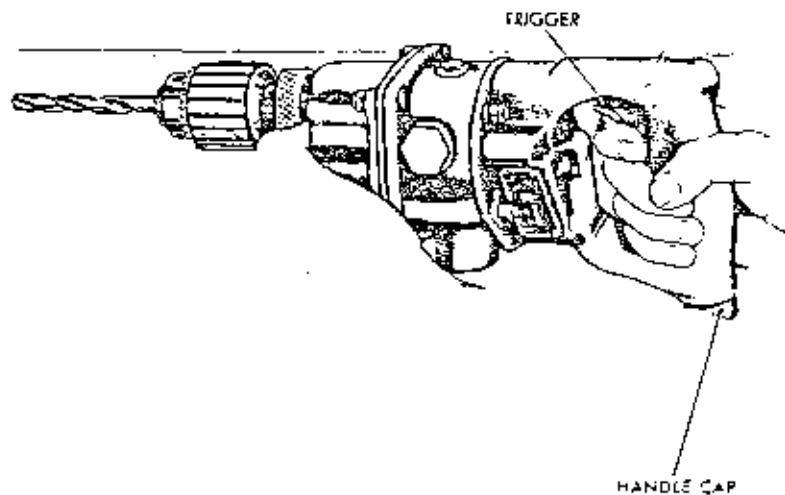


Figure 1-2-15.—Controls of a pneumatic drill.

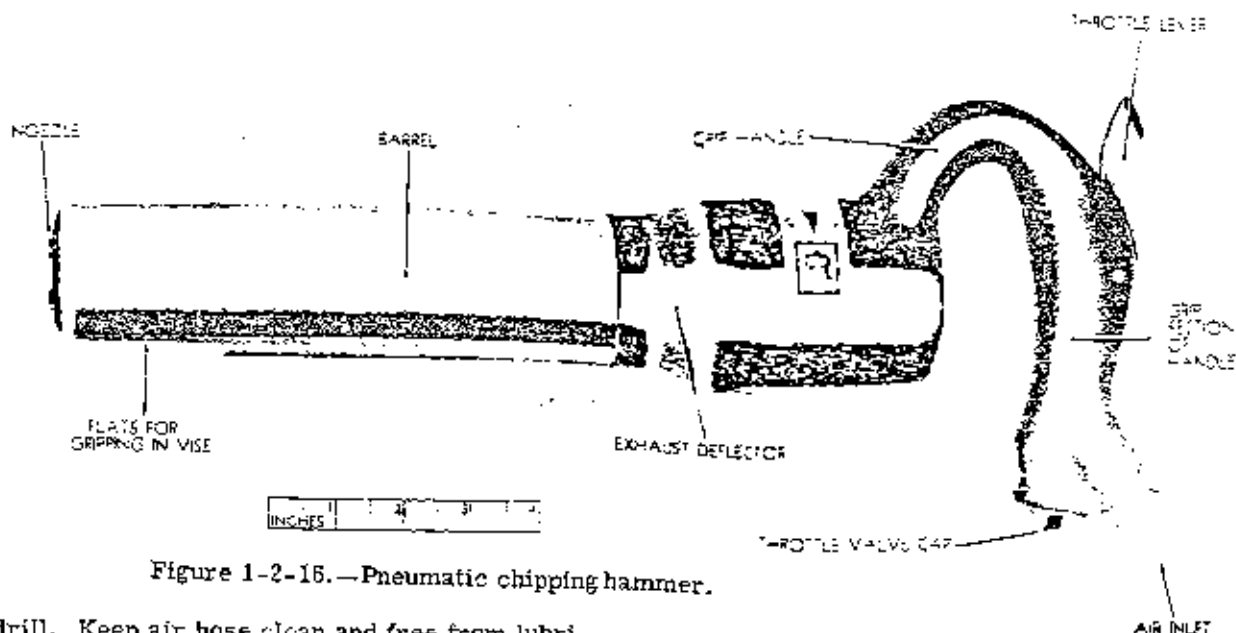


Figure 1-2-16.—Pneumatic chipping hammer.

drill. Keep air hose clean and free from lubricants.

Make certain the tool being used in the chuck is properly secured and check the operation of the trigger to make sure it is working properly. Check the pneumatic drill for evidence of exterior damage. Tighten all loose fittings, nuts and bolts. Make sure the drill motor has been properly lubricated in accordance with the manufacturer's specifications.

PNEUMATIC CHIPPING HAMMER

The pneumatic chipping hammer (fig. 1-2-16) consists basically of a steel piston which is reciprocated (moved backward and forward alternately) in a steel barrel by compressed air. On its forward stroke the piston strikes the end of the chisel, which is a sliding fit in a hexagon nozzle pressed into the barrel. The rearward stroke is cushioned by compressed air to prevent any metal-to-metal contact. Reciprocation of the piston is automatically controlled by a valve box assembly located on the rear end of the barrel. Located on the rear end of the barrel is a grip handle, containing a poppet-type throttle valve.

The throttle valve is actuated by a throttle lever which protrudes from the upper rear of the grip handle for thumb operation. Projecting from the butt of the handle is an air inlet. The handle is threaded onto the barrel and is prevented from unscrewing by a locking ring. Surrounding and retaining the locking ring is an exhaust deflector. This deflector may be located in any of four positions around the barrel in order to throw the stream of exhaust air in the desired direction.

The pneumatic hammer may be used for beveling, calking or beading operations, and for drilling in brick, concrete, and other masonry. The chipping hammer is especially useful for preparing metal surfaces for painting.

Chipping hammers should not be operated without safety goggles and all other persons

in the immediate vicinity of the work should wear goggles.

While working never point the chipping hammer in such a direction that other personnel might be struck by an accidentally ejected tool. When chipping alloy steel or doing other heavy work, it is helpful to dip the tool in engine lubricating oil about every 8 inches of the cut and make sure the cutting edge of the tool is sharp and clean. This will allow faster and easier cutting and will reduce the possibility of the tool breaking.

When nearing the end of a cut, ease off on the throttle lever to reduce the intensity of the blows. This will avoid any possibility of the chip or tool flying.

If for any reason you have to lay the chipping hammer down, always remove the tool from the nozzle. Should the chipping hammer be accidentally started when the tool is free, the blow of the piston will drive the tool out of the nozzle with great force and may damage equipment or injure personnel.

PORTABLE PNEUMATIC IMPACT WRENCH

The portable pneumatic impact wrench (fig. 1-2-17) is designed for installing or removing nuts and bolts. The wrench comes in different sizes and is classified by the size of the square anvil on the drive end. The anvil is equipped with a socket lock which provides positive locking of the socket wrenches or attachments. The wrench has a built-in oil reservoir and an adjustable air valve regulator which adjusts the torque output of the wrench. The torque regulator reduces the possibility of shearing or damaging threads when installing nuts and bolts to their required tension.

Nearly all pneumatic wrenches operate most efficiently on an air pressure range of 80 to 90 psi. A variation of plus or minus 5 pounds is serious. Lower pressure causes a decrease in the driving speeds while higher pressure

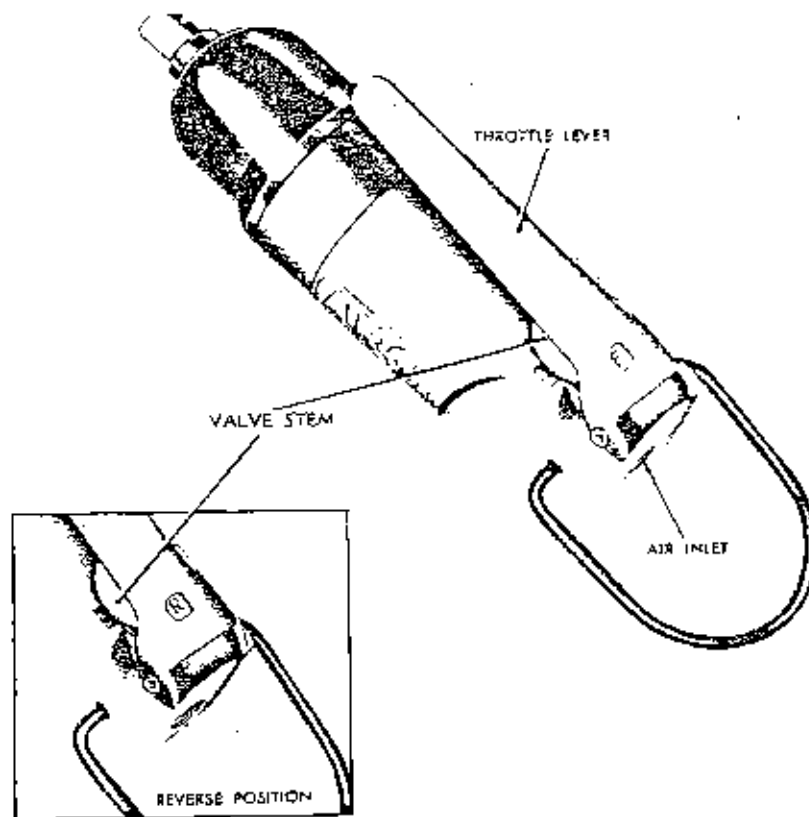


Figure 1-2-17.—Portable pneumatic impact wrench.

causes the wrench to overspeed with subsequent abnormal wear of the motor impact mechanisms.

The throttle lever located at the rear of the pneumatic wrench provides the means for starting and stopping the wrench. Depressing the throttle lever starts the wrench in operation. Upon release, the lever raises to its original position stopping the wrench.

The valve stem is seated beneath the pivot end of the throttle lever. Most wrenches have a window cut in the throttle lever so that the markings on the upper surface of the valve stem will be visible. Two letters, "F" and "R," have been engraved on the head of the valve stem to indicate the forward (clockwise) and reverse (counterclockwise) rotation of the anvil. To change from forward to reverse rotation, or vice versa, turn the valve stem 180° until the desired marking is visible through the window in the throttle lever. When the valve stem is in proper position, the valve stem pin engages a recess on the under side of the valve stem, preventing accidental turning of the stem.

The air valve regulator is located at the bottom and towards the rear of the wrench. Using a screwdriver and altering the setting of the air regulator up to 90°, either to the right or left, reduces the torque from full power to zero power.

Before operating the pneumatic impact wrench make sure the socket or other attachment you are using is properly secured to the anvil. It is always a good idea to operate the wrench free of load in both forward and reverse directions to see that it operates properly. Check the installation of the air hose to make sure it is in accordance with the manufacturer's recommendation.

COMMON POWER MACHINE TOOLS

Small power machine tools are, generally speaking, not portable. All work that is to be done must be brought to the shop where the machine is set up. Only the most common types of power machine tools will be discussed in this text. There are many power machine tools used by people of specific ratings but most of them require a degree of skill that can be learned only by working with them.

DRILL PRESS

The drill press is an electrically operated power machine that was originally designed as a metal-working tool. As such its applications would be limited in the average shop. Available accessories, plus jigs and special techniques, now make it a versatile wood-working tool as well.

There are two basic types of drill presses.

They are the bench-type drill press (fig. 1-2-18) and the upright-type drill press (fig. 1-2-19). These two types drill presses are basically the same, the difference being in the mounting. As the names suggest, the bench-type drill press is mounted on a work bench and the upright-type drill press is mounted on a pedestal on the floor.

Drill presses are manufactured in a number of sizes, however, only the small size drill press will be discussed in this text. The drill presses most commonly found in shops

MEASURING THE DIAMETER OF A HOLE WITH A SMALL HOLE GAGE

To measure the diameter of a hole from $1/8''$ to $1/2''$ in diameter, use a small-hole gage. (See fig. 2-1-20.) The four gages in a set cover this range of hole sizes so you must choose the proper gage for the size hole you are measuring. Insert the gage into the hole and adjust it to the hole size by turning the knurled tip of the handle. When you can feel the slight drag of the ball end on the sides of the hole, withdraw the gage. The size of the hole can then be determined by measuring the ball end of the gage with a micrometer caliper. Check part I, section 1 of this course if it is necessary to refresh your memory on how to read a micrometer.

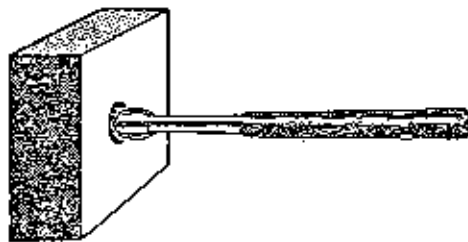


Figure 2-1-20.—Measuring the diameter of a hole with a small hole gage.

MEASURING THE DIAMETER OF A HOLE WITH A TELESCOPING GAGE

To measure the diameter of a hole from $1/2''$ to $6''$ in diameter, select from a set of telescoping gages the one whose range includes the size you need. Loosen the knurled nut at the end of the handle, and telescope the adjustable end of the gage to a size slightly smaller than the hole and retighten the nut. Insert the gage into the hole as shown in figure 2-1-21, loosen the nut to permit the spring-loaded adjustable end to expand to the hole diameter, and tighten the nut. The spring loaded contact of the adjustable end will assure proper contact. Make sure, however, that the gage is held with the

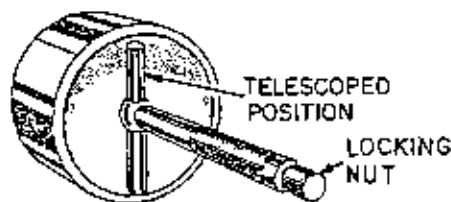


Figure 2-1-21.—Using a telescoping gage.

telescoping end at right angles to the axis of the hole to measure the true, maximum diameter. Remove the gage and measure the setting with an outside micrometer caliper.

MEASURING THE DIAMETER OF A HOLE WITH AN INSIDE MICROMETER CALIPER

To measure the diameter of small holes from $0.2''$ to $1''$ in diameter, an inside micrometer caliper of the jaw type as shown in figure 2-1-22A may be used. Note that, in the inset the figures on both the thimble and the barrel are reversed, increasing in the opposite direction from those on an outside micrometer caliper, because this micrometer reads inside measurements. As you turn the thimble clockwise on this micrometer, the measuring surfaces move farther apart and the reading increases. On an outside micrometer caliper, as you turn the thimble clockwise, the measuring surfaces move closer together and the reading decreases.

For holes from $2''$ up to several feet in diameter, select the inside micrometer having

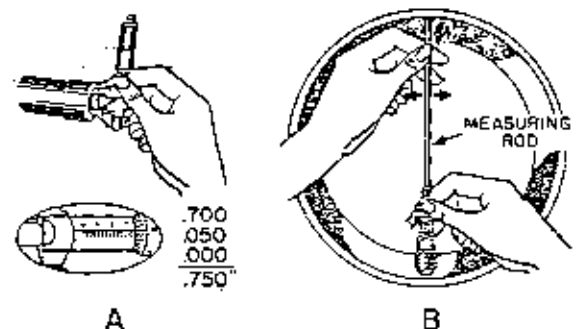


Figure 2-1-22.—Measuring an inside diameter with an inside caliper.

measuring rods whose range includes the required dimension. The extension rod marked "6-7," for example, when inserted into the head of the micrometer, will measure inside diameters from $6''$ to $7''$. The shoulder on the rod must seat properly to ensure a correct reading. Figure 2-1-22B shows that, for large measurements, both hands are used to set the micrometer for checking a diameter. Hold one end in place with one hand as you "feel" for the maximum possible setting by moving the other end from left to right, and in and out of the hole with the other hand. When no left-to-right movement is possible, and a slight drag is noticed on the in-and-out swing, take the reading.

MEASURING THE DISTANCE BETWEEN OUTSIDE SURFACES WITH A VERNIER CALIPER

To measure the distance between outside surfaces or the outside diameter of round stock with a vernier caliper, steady the stock with one hand and hold the caliper in the other as shown in figure 2-1-23. In the figure the clamping screws are at A and B; the horizontal adjusting

screw nut is at C. With A and B loose, slide the movable jaw toward the piece being measured until it is almost in contact. Then tighten A to make C operative. With C, adjust the movable jaw to the proper feel and secure the setting with B. The reading can then be taken as explained in an earlier section of this chapter.

MEASURING THE DISTANCE BETWEEN INSIDE SURFACES WITH A VERNIER CALIPER

To measure the distance between inside surfaces, or the inside diameter of a hole, with a vernier caliper, use the scale marked "inside." Figure 2-1-24 shows the measuring points in place. Remember that if you are using a vernier caliper with both metric and English scales, the scales appear on opposite sides of the caliper and apply only to outside measurements. Then, to get correct inside measurements, you add to the actual reading the measuring point allowance for the size of caliper you are using. Take this allowance from the table given in part I section 1 or the manufacturer's instructions. The actual measurement in this case is made in the same manner as taking an outside measurement.

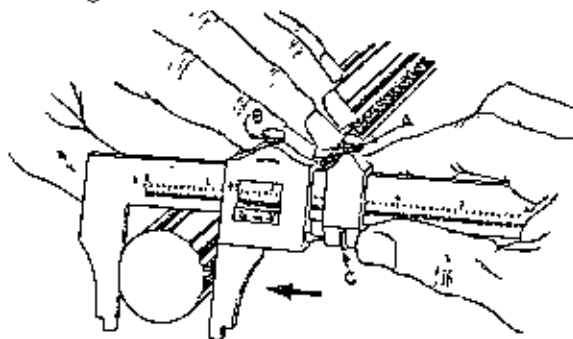


Figure 2-1-23.—Measuring an outside diameter with a vernier caliper.

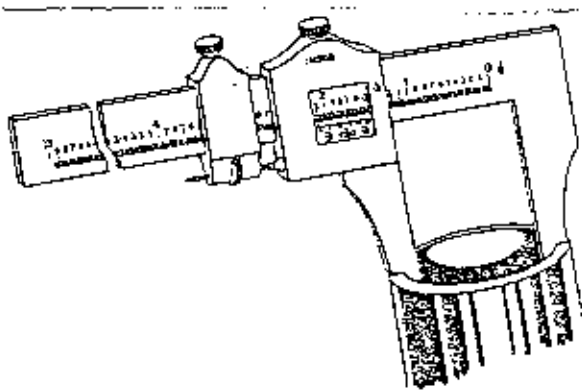


Figure 2-1-24.—Measuring an inside diameter with a vernier caliper.

MEASURING ROUND STOCK WITH A MICROMETER

When measuring the diameter of a small piece of round stock, hold the stock to be measured in one hand. Hold the micrometer in the other hand so that the thimble rests between the thumb and the forefinger. (See fig. 2-1-25.) The third finger is then in a position to hold the frame against the palm of the hand. The frame is supported in this manner and makes it easy to guide the work over the anvil. The thumb and forefinger are in position to turn the thimble either directly or through the ratchet and bring the spindle over against the surface being measured.

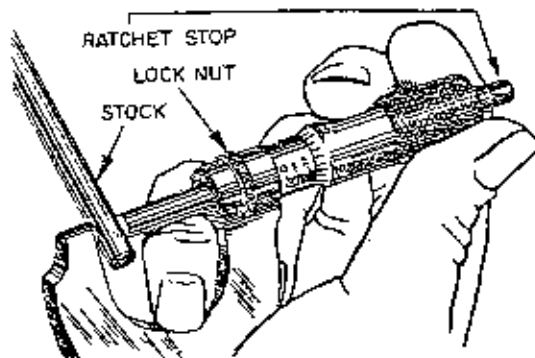


Figure 2-1-25.—Measuring round stock with a micrometer caliper.

Turn the spindle down to contact by "feel," or else use the ratchet stop. Your feel should produce the same contact pressure and therefore the same reading as that produced when the ratchet stop is used. Develop your "feel" by measuring a certain dimension both with and without the aid of the ratchet stop. When you have the correct feel, you will get the same readings by both methods.

In measuring round stock the feel must be very light because there is only a line contact between the spindle and the stock and the anvil and the stock. Therefore the contact area is exceptionally small, causing a proportionally high contact pressure per unit of area. This would tend to give a reading smaller than the true reading unless the light feel is used. In measuring a ball from a ball bearing, the contact is at only two points, so the contact area is very small, indicating a tremendous pressure per unit of area. This causes the reading only the lightest possible contact pressure to be the true reading.

Hold the micrometer in the right hand as long as is necessary to make the measurement. Wrapping the thumb around the frame for too long a time will cause the metal and the work to heat. Read the object being measured. The micrometer should be held in the right hand as long as is necessary to make the measurement.

MEASURING A FLAT SURFACE WITH A MICROMETER CALIPER

When measuring a flat surface with a micrometer caliper, the entire area of both the anvil and the spindle is in contact with the surface being measured. This causes a proportionally low contact pressure per unit of area. Therefore the "feel" should be slightly heavier than when measuring round stock.

On large flat work, it is necessary to have the work stationary and positioned to permit access to the micrometer. The proper method of holding a micrometer when checking a part too large to be held in one hand is shown in figure 2-1-26. The frame is held by one hand to position it and to locate it square to the measured surface. The other hand operates the thimble either directly or through the ratchet. A large flat surface should be measured in several places to determine the amount of variation. It is good practice to lock the spindle in place with the locknut before removing the micrometer from the part being measured. After doing this the measurement indicated on the thimble scale can then be read.

To retain a particular setting, in cases where several pieces are to be gaged, lock the spindle in place with the locknut. When a piece is "gaged" with a micrometer with its spindle locked to a setting, the piece can quickly be identified as oversize, correct size, or under-size.

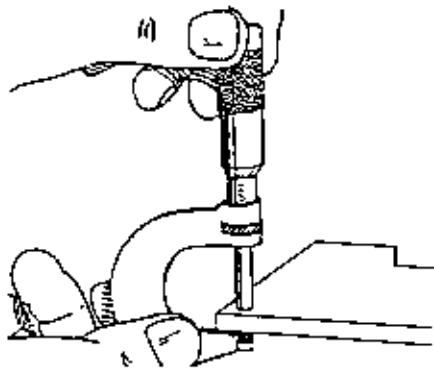


Figure 2-1-26.—Measuring flat stock with a micrometer caliper.

CORRECT MICROMETER ZERO SETTING

If an outside micrometer caliper does not read zero when the spindle touches the anvil, and both are clean at the point of contact, the zero setting should be corrected. This will eliminate the necessity of adding or subtracting a "zero correction" numerically to each reading as would otherwise be necessary if this adjustment were not made.

The zero setting on all micrometers is not made in exactly the same way. Refer to either the instructions that come with the micrometer or to the manufacturer's catalog for specific directions for a particular tool.

For example, The Brown & Sharpe Manufacturing Co. includes with each micrometer the instructions which follow, with an illustration of each step.

1. Carefully clean the measuring surfaces by pulling a piece of soft paper between the surfaces while the anvil and spindle are in light contact with the paper. Do not use hard paper. (See fig. 2-1-27A.)
2. With the anvil and spindle apart, unlock thimble cap with spanner wrench; then tighten cap lightly with fingers to bring light tension between thimble and spindle. (See fig. 2-1-27B.)
3. Bring anvil and spindle together by turning spindle and set zero line on thimble to coincide with line on sleeve. (See fig. 2-1-27C.)
4. Move spindle away from anvil by turning spindle and not by turning thimble. (See fig. 2-1-27D.)
5. Holding thimble only, tighten cap with fingers. Do not touch frame. (See fig. 2-1-27E.)
6. Lock cap with wrench, still holding thimble only, and the adjustment is complete. (See fig. 2-1-27F.)

It is IMPORTANT that you grip the micrometer as shown in each figure when making that particular adjustment. After completing the adjustment, check zero setting and make sure it is correct.

MEASURING THE PITCH OF A THREAD

The screw pitch gage has teeth which correspond to standard thread sections. To measure the pitch of a thread, compare it with the standards of the screw pitch gage by holding a gage leaf to the thread being gaged until you find an exact fit. If possible, look at the fit toward a source of light, as a difference of one thread per inch, in the finer threads, is not easily detected.

As shown in figure 2-1-28, single and multiple threads can be gaged. The thread at A is single pitch, as the travel is one thread per revolution as shown by the dotted lines. The thread at B is a double pitch thread as shown by its dotted lines, and the travel is two threads per revolution. In this figure you see that the gage fits a certain thread, whether it be single or double pitch, internal, or external thread.

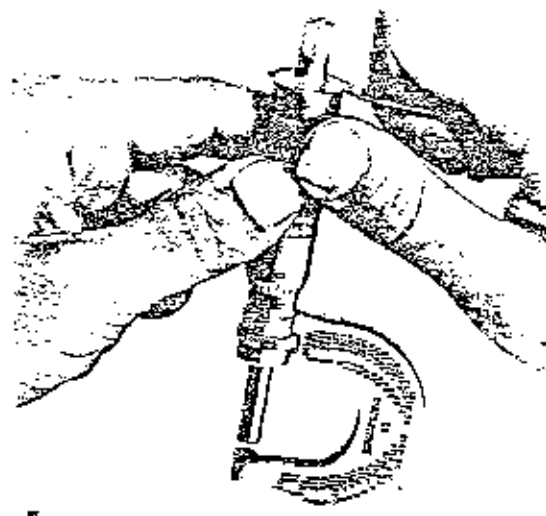
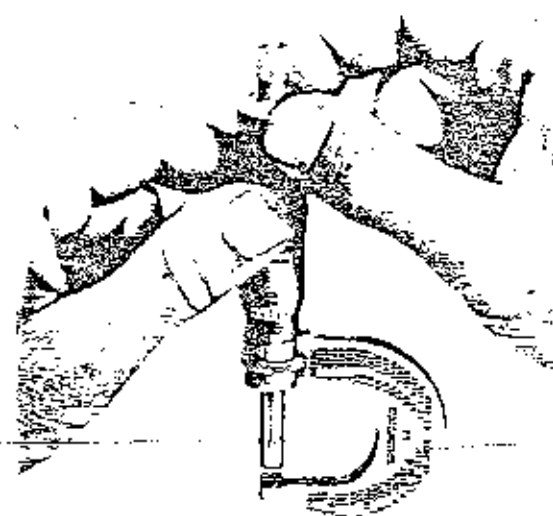
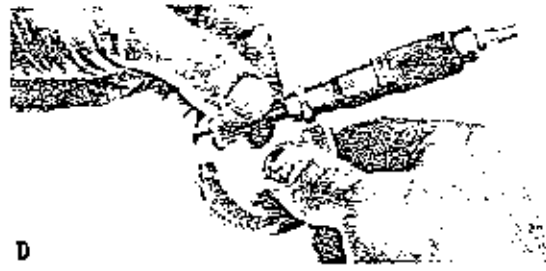
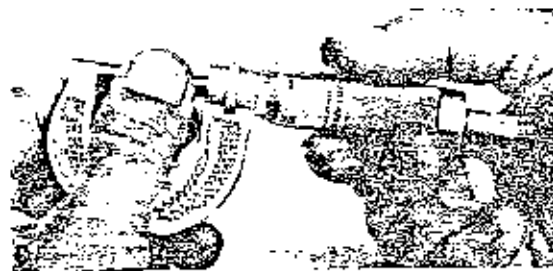
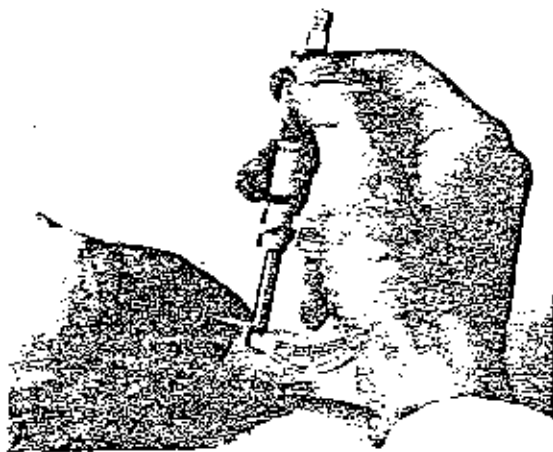


Figure 2-1-27.—Correcting zero setting on a micrometer.

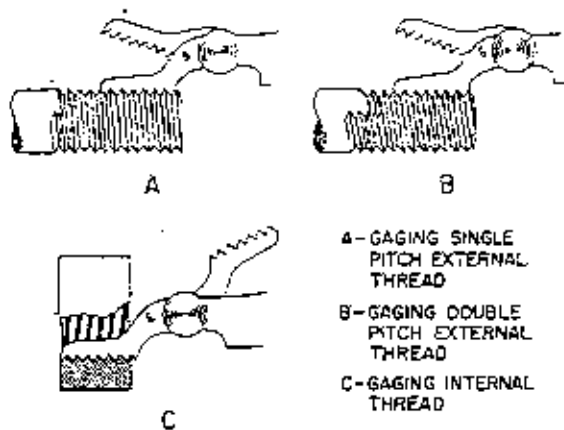


Figure 2-1-28.—Using a screw pitch gage.

MEASURING THE GAGE OF SHEET METAL

To measure the gage of a piece of sheet metal, first remove any burr from the place where you will apply the sheet metal gage.

The gage shown in figure 2-1-29 is used for gaging nonferrous sheet and wire. This gage, and others similar to it, are listed in the "Tables of useful information" under wire and sheet metal gages. Select, from the five gages listed in this table, the one that applies to the sheet of metal or wire you want to gage. For instance, column 2 of the above mentioned table tells you that the American Wire Gage shown in figure 2-1-29 is the one to use for nonferrous sheet and wire. Notice that usually each of the five gages has its own decimal equivalent for a particular gage number. If you have a piece of iron wire that is 0.016" in diameter, its correct identification is 0.016" diameter iron wire, B.W.G. (British Wire Gage) No. 27. If you have a piece of steel music wire that is 0.016" in diameter, you identify it as 0.016" diameter steel music wire, Music Wire Gage No. 6.

After the right gage has been selected, apply the gage to the wire, or to the edge of the sheet as shown in figure 2-1-29. The number opposite the slot that fits the wire or sheet is its gage number. The decimal equivalent is stamped on the opposite face of the gage.

To eliminate errors that might occur due to using the wrong gage, or if gages are not available, take a micrometer reading in decimal fractions of an inch and state the name of the material such as 0.014" hot rolled sheet steel, 0.010" brass wire, etc. Then to find the gage number, you can refer to the table on Wire and Sheet Metal Gages and find the material, the name of the proper gage, and the gage number corresponding to the decimal fraction obtained by taking a micrometer reading.

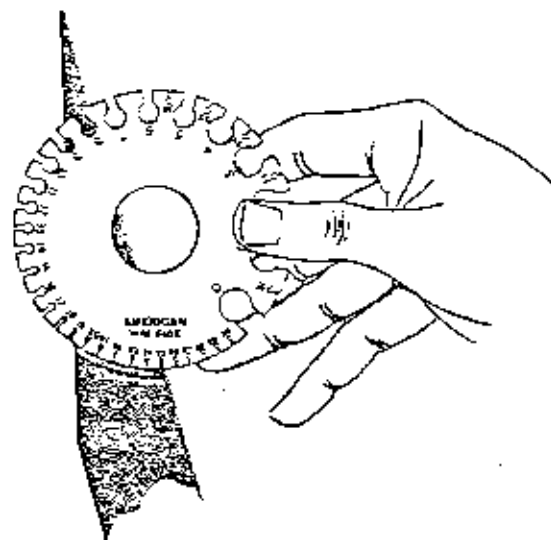


Figure 2-1-29.—Using a wire gage to measure sheet metal.

LAYING OUT

Laying out work is the careful measuring and marking of stock prior to cutting and shaping the work. Close attention to details in layout is necessary to ensure successful progress on a job. The layout tools should be selected and used with care to ensure accurate layout work.

The plan for laying out a job may be taken from a blueprint or a sketch. The important thing to remember is to plan the layout to avoid delays in getting the job done and avoid waste of material.

Wood and metal are two common materials you will work with.

A marking awl or scriber is recommended for marking metal. An old saw file ground to a fine point makes a very good scriber if a commercial type scriber is not available. A center punch, or prick punch that is ground to a fine point, is valuable for marking locations for drill holes, bends, saw cuts, etc. To lay out lines on wood, pencils or a knife may be used for marking. To lay out rough work, a heavy carpenter's pencil may be used. To lay out lines for finish carpentry, a regular lead pencil sharpened to a conical point is used. For extremely accurate work, use a knife line for layout work.

The operations that are explained in this section are operations that you will perform when laying out lines on stock material prior to cutting and shaping the work.

SQUARING A LINE ON STOCK WITH A COMBINATION SQUARE

To square a line on stock with a combination square, place the squaring head on the edge of the stock, as shown in figure 2-2-1, and draw the line along either edge of the blade. The line will be square with the edge of the stock against which the squaring head is held; that is, the angle between the line and the edge will be 90 degrees.

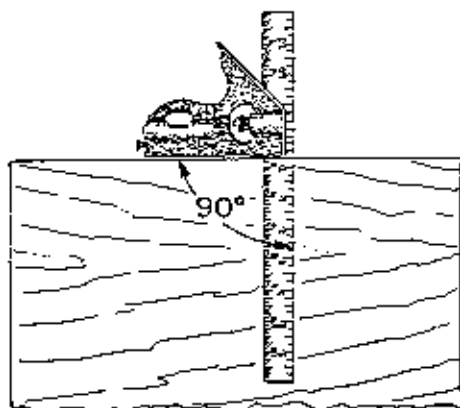


Figure 2-2-1.—Squaring a line on stock with a combination square.

LAYING OUT A 45° ANGLE ON STOCK WITH A COMBINATION SQUARE

To lay out a 45° angle on stock, using a combination square, place the squaring head on the edge of the stock, as shown in figure 2-2-2, and draw the line along either edge of the blade. The line will be at 45° with the edge

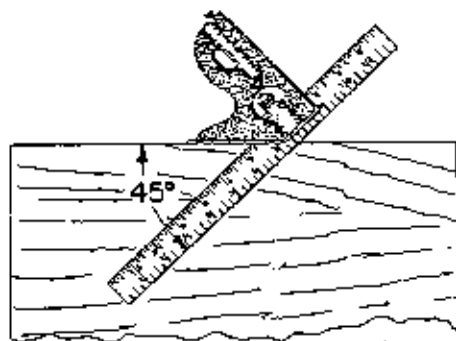


Figure 2-2-2.—Using a combination square to lay out a 45° angle.

of the stock against which the squaring head is held.

DRAWING LINES PARALLEL TO AN EDGE WITH A COMBINATION SQUARE

To draw lines parallel to an edge, using a combination square, extend the blade from the squaring head a certain distance, such as the 2 inches shown in figure 2-2-3. Secure the blade at this position. Make a line parallel to the edge of the stock by holding the scratch awl or a pencil at the end of the blade as you move the square along the edge. All lines so made, with different blade settings, will be parallel to the edge of the stock, and parallel to each other.

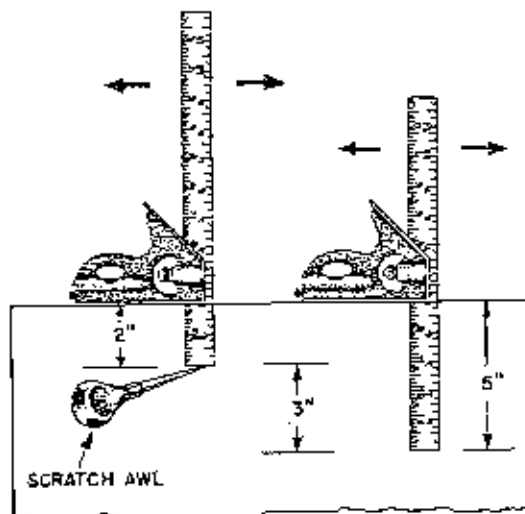


Figure 2-2-3.—Drawing parallel lines with a combination square.

DRAWING ANGULAR LINES WITH THE PROTRACTOR HEAD OF A COMBINATION SQUARE

Remove the squaring head of the square and install the protractor head. Loosen the adjusting screw of the protractor head and rotate the blade to where the desired angle lines up with the index mark on the body of the head. The setting shown in figure 2-2-4 is 60 degrees. Retighten the screw to hold the setting. Hold the body of the protractor head in contact with a true edge of the work with the blade resting on the surface. Scribe or draw lines along the edge of the blade on the surface of the work. The angle set on the scale determines the angle

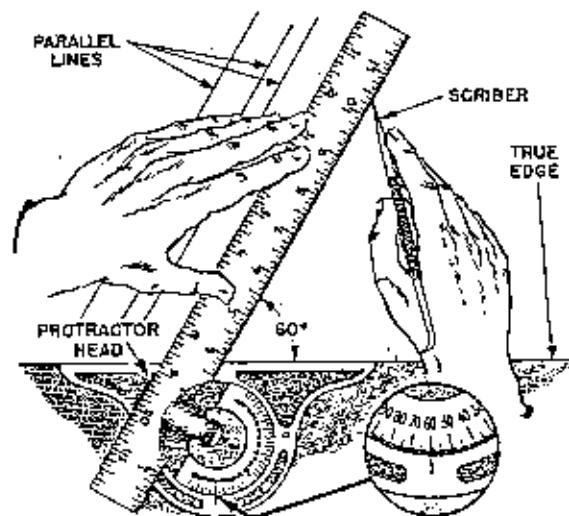


Figure 2-2-4.—Drawing angular lines with a protractor head of a combination square.

laid out on the work. All lines drawn with the same setting, and from the same true edge of the work, will be parallel lines.

FINDING THE CENTER OF ROUND STOCK

To locate the center of round stock, one of three tools is commonly used: the combination square, the hermaphrodite caliper, or a surface gage.

To use the combination square set for finding the center of round stock, remove the square head and protractor head by loosening their clamping nuts and withdrawing the rule. After removing these two heads, hold the center head firmly in place on the end of the shaft, as shown in figure 2-2-5, so that the shaft rests in the V of the center head and is in contact with the back of the rule. This will locate the one edge of the rule so that it passes through the center of the shaft. Scribe a line along this edge. Then relocate the center head at about 90° from this first line and scribe a second line. The intersection of these two lines will be the center of the end of the shaft.

Figure 2-2-6 shows the hermaphrodite caliper being used for locating the center of the end of a shaft. Hold the curved leg of the caliper against the shaft with one hand as you swing the arc holding the joint of the caliper with the other hand. The four points around

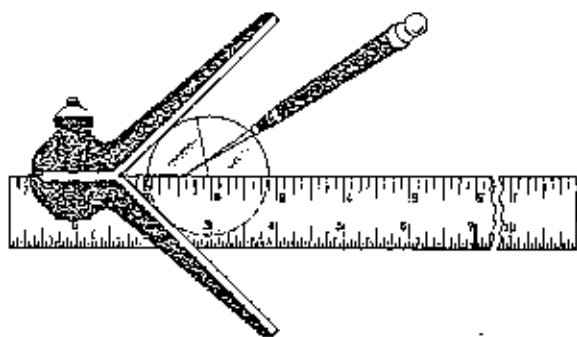


Figure 2-2-5.—Locating a shaft center with a combination square.

the shaft where the curved leg is to be held are located approximately 90° apart. Any of the three patterns of scribed lines shown in figure 2-2-6 will serve as a guide to enable you to punch the center of the end of the shaft.

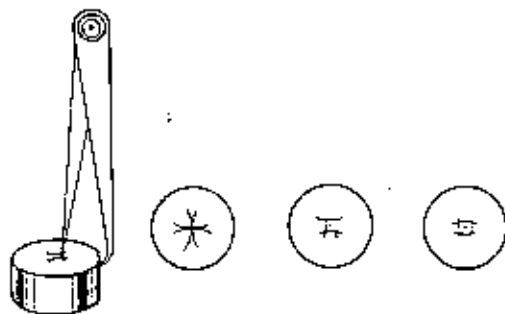


Figure 2-2-6.—Locating the center of a shaft with hermaphrodite calipers.

The method for finding the center of a shaft by using a surface gage, vee-block, and a surface plate or similar true surface, is shown in figure 2-2-7. The vee-block holds the shaft at a fixed distance from the plate. The surface gage holds a scriber at a selected fixed distance from the plate. To locate the center on the end of the shaft, scribe a line that will be near the center. Rotate the shaft about 90° about its axis as it rests in the vee-block and scribe another line. When four lines have been scribed, they will serve as a guide to punching the center of the shaft. Do not move the setting of the scriber on the surface gage while making these layout lines.

When using a hermaphrodite caliper or a surface gage for finding the center of round stock, the methods shown will only give you an approximate center. The exact center can

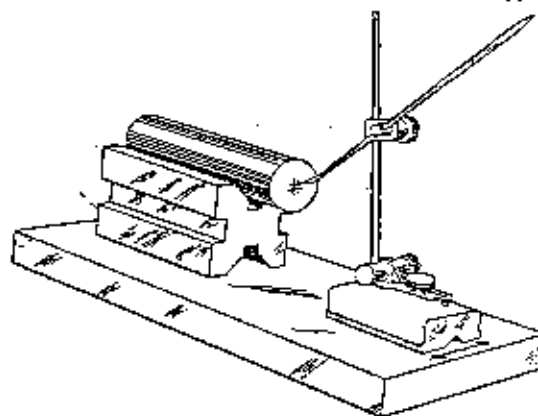


Figure 2-2-7.—Locating the center of a shaft with a surface gage.

be found by drawing lines diagonally across the patterns scribed. Where the diagonal lines cross will be the exact center of the shaft.

When using any of the methods described for locating the center of a shaft, make sure the end of the shaft is reasonably square and clean. The use of layout dye or chalk, to emphasize the layout lines, will make them easier to see.

SOLVING BASIC PROBLEMS WITH THE FRAMING SQUARE

Of all the layout tools in the woodworker's kit, the framing square is far and away the most generally useful. The problems that can be solved when laying out work with the square are so many and varied that whole books have been written on the square alone. Only a few of the most common uses of the square can be presented in this course.

The framing square is used most frequently to find the length of the hypotenuse (longest side) of a right triangle when the lengths of the other two sides are known. This is the basic problem involved, for example, in laying out or determining the length of a roof rafter, a brace, or any other member which forms the hypotenuse of an actual or an imaginary right triangle.

Figure 2-2-8 shows you how the framing square is used to determine the length of the hypotenuse of a right triangle with the other sides, each 12 in. long. Place a true, straight edge on a board, and set the square on the board so as to bring the 12-in. mark on the tongue and the 12-in. mark on the blade even with the edge of the board. Draw the pencil marks shown in the second view. The distance between these marks, as measured along the edge of the board, is the length of the hypotenuse of a right triangle with the other sides each 12 in. long. You will find that the distance, which is called the **BRIDGE DISTANCE**, measures just a shade under 17 in. To be exact it is 16.97 in., as shown in the figure, but for most practical purposes the 16.97 may be rounded off to 17 in.

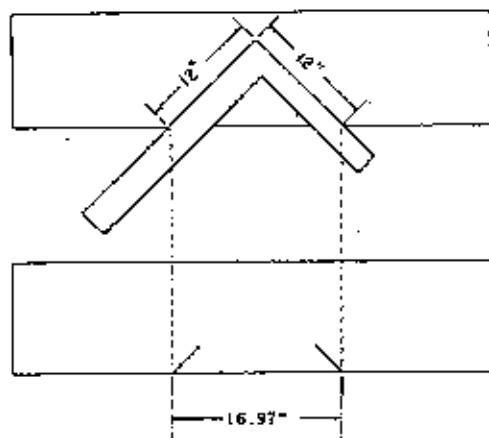


Figure 2-2-8.—Basic problem solved by the framing square.

In figure 2-2-8 the hypotenuse of the triangle is horizontal. In most practical situations, however, the triangle in question has one of the shorter sides horizontal and the other vertical. When this is the case, the length of the horizontal shorter side is called the **RUN** and the length of the vertical shorter side is called the **RISE**.

LAYING OUT 90° AND 45° ANGLES WITH A FRAMING SQUARE

In laying out 90° and 45° angles with a framing square, the lumber you work with will nearly always have to be squared on the ends. This will make it necessary to lay out a line at a 90° angle with respect to the edge of the board. This line should be as close to the end of the board as possible to avoid undue waste of material. When doing this job with a framing square, place the blade of the square along one edge of the board, and mark along the outside edge of the tongue, as shown in figure 2-2-9.

Ninety degree mitered corners are made by placing two 45° cuts together. To lay out a 45° angle for making the cuts, place the framing square on the face of the board with an equal number of graduations on the tongue and blade

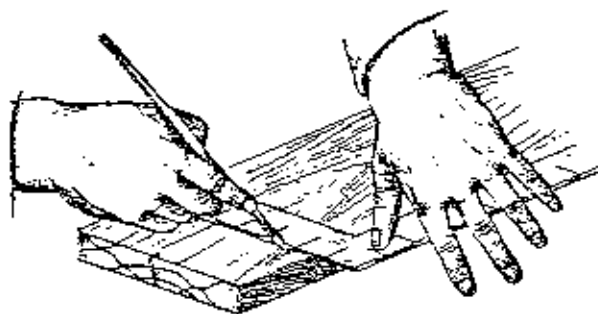


Figure 2-2-9.—Laying out a 90° angle with a framing square.

as shown in figure 2-2-10, and mark along the edge of the square nearest the end of the board. If you want the angle with respect to the edge of the board to be opposite, merely turn the square over on its other side and again mark along the edge nearest the end. By making your layout lines nearest the edge of the board you will save material.

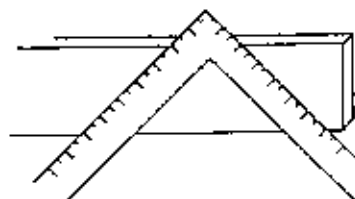


Figure 2-2-10.—Laying out a 45° angle with a framing square.

LAYING OUT ROUNDED CORNERS ON SQUARE STOCK

To lay out a rounded corner on square stock, you will need a square and a set of dividers. Find the center of the arc (fig. 2-2-11) by measuring from the corner of the stock along the adjacent sides, a distance equal to the radius of the arc (A-A). Use a square and square in from points (B-B). The intersection of these lines will locate the center of the arc (C).

Set the dividers to a measurement equal to the distance of the radius of the arc (C-B).

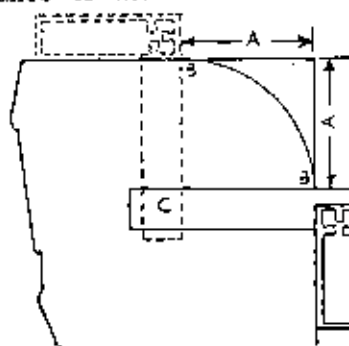


Figure 2-2-11.—Laying out a rounded corner on square stock.

Place one leg of the dividers at C, (fig. 2-2-11), and rotate the dividers around this point as a center, allowing the other leg to scratch lightly the surface of the stock. This arc should fall in line with the edges of the board at points (B-B).

FASTENING PAPER TO A DRAWING BOARD TO DRAW LINES

To fasten paper to a drawing board, place it on the board about an inch from the left-hand edge and near the top. (See fig. 2-2-12.) Placing the paper near the top of the board will keep the head of the T-square from running off the edge when you are working near the bottom of the paper.

Then true up the paper with the T-square blade, and secure it with thumbtacks or drafting tape at the upper corners only. The paper will then lie flat on the board.

To draw parallel horizontal lines, hold the head of the T-square to the edge of the board and draw lines as shown in figure 2-2-13.

To draw lines with a triangle and T-square, refer to figure 2-2-14 and note the directional arrows. Experience has shown that the best speed and accuracy are obtained by drawing your lines in these ways, provided of course, you are right handed; this applies to the 30°-60° triangle as well as the 45° shown in figure 2-2-14.

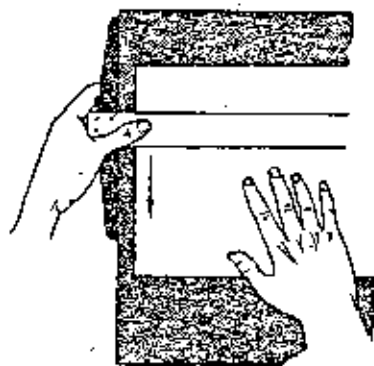


Figure 2-2-12.—Squaring paper on a drawing board with a T-square.

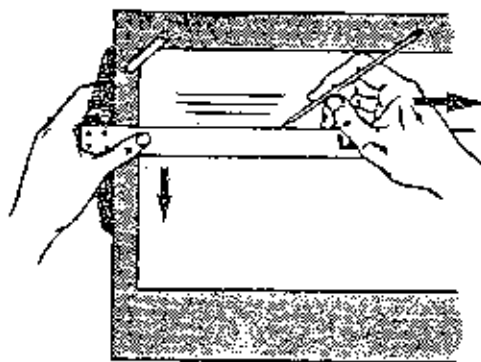


Figure 2-2-13.—Drawing horizontal lines with a T-square.

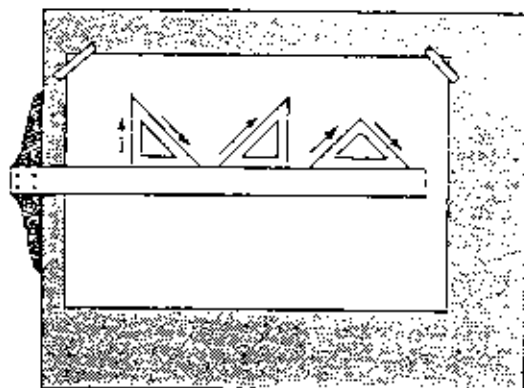


Figure 2-2-14.—Drawing lines at an angle with a T-square and triangles.

DRAWING A LINE PARALLEL TO AN EDGE WITH A MARKING GAGE

To draw a line parallel to an edge with a marking gage, first determine the distance the line must be from the edge of the stock. Adjust the marking gage by setting the head the desired distance from the spur. Although the bar of a marking gage is graduated in inches, the spur may work loose or bend. If this occurs, accurate measurement should be made with a rule between the head and spur. (See fig. 2-2-15A.) To draw a line after setting the gage, grasp the head of the gage with the palm and fingers as shown in figure 2-2-15B; extend the thumb along the beam towards the spur. Press the head firmly against the edge of the work to be marked, and with a wrist motion tip the gage forward until the spur touches the work. Push the gage along the edge to mark the work, keeping the head firmly against the edge of the work.

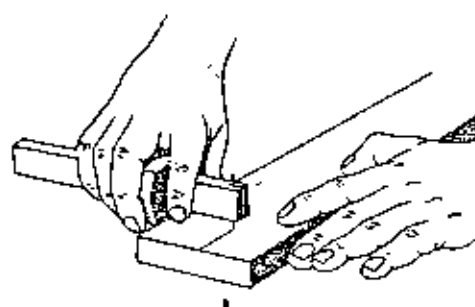
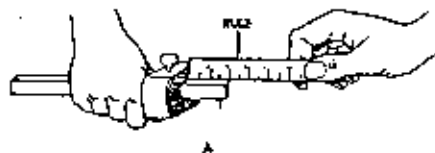


Figure 2-2-15.—Using the marking gage.

DIVIDING A DIMENSION EQUALLY WITH A RULE

To divide a dimension, such as the 4" width of the board in fig. 2-2-16, into any given number of equal parts, place a rule on its edge across the face of the board. With the end of the rule at one edge of the board, adjust the rule at an angle to the other edge so that an inch graduation falls on the other edge. The 9" graduation would give nine equal divisions at the inch lines. The 6" graduation would give 6 equal divisions at the inch lines, or 3 by marking at the 2- and 4-inch lines, as shown. Then mark the divisions on the surface with a sharp pencil (fig. 2-2-16) and draw lines parallel with the working edge of the board.

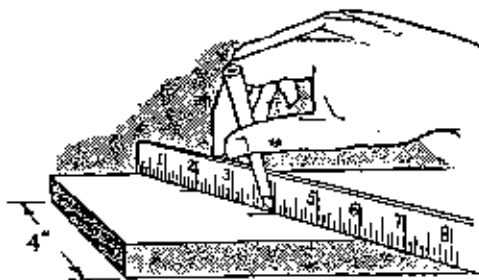


Figure 2-2-16.—Dividing a dimension equally with a rule.

DIVIDING A LINE INTO EQUAL SEGMENTS WITH A DIVIDER

To divide a line equally with a divider, step it off in any size steps, as shown in figure 2-2-17, working from one end of the line to the other. When the end is reached, you will probably have a division which is smaller than the rest. This is a trial-and-error method; so either increase or decrease the setting on the divider until you obtain the required number of equal divisions.

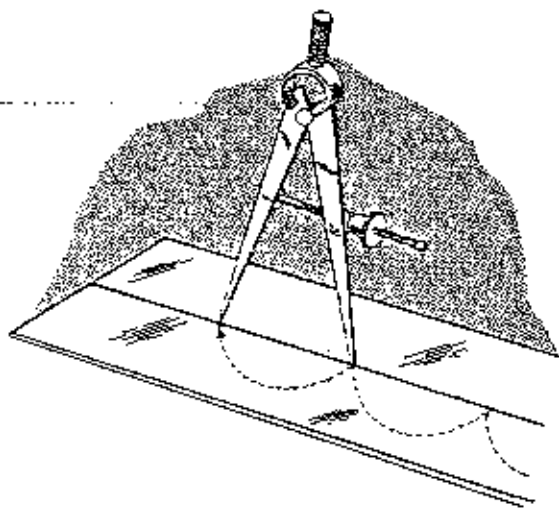


Figure 2-2-17.—Dividing a line into equal segments with a divider.

SCRIBING A LINE TO A SURFACE WITH A DIVIDER

Scribing a line to a surface is a skill used when doing such jobs as fitting linoleum into corners or curves, or fitting a piece of stock, as shown in figure 2-2-18, to a curved surface. In figure 2-2-18A, you see the complete fit. In 2-2-18B the divider has scribed a line from left to right. When scribing horizontal lines, the legs of the divider must be kept plumb (one above the other). When scribing vertical lines, the legs must be kept level. Therefore, to scribe a line to a surface, set the divider so that one leg will follow the irregular surface, and the other leg will scribe a line on the material that is being fitted to the irregular surface. (See fig. 2-2-18B.)

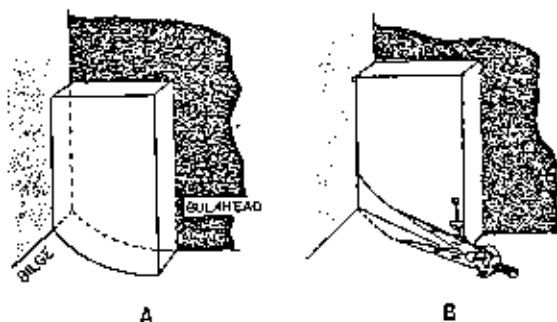


Figure 2-2-18.—Scribing a line to a surface.

When scribing a line on a level surface, as in fitting linoleum to a curved bulkhead, figure 2-2-19, keep the line joining the points of the divider perpendicular to the straight bulkhead from which you start to scribe.

LAYING OUT A PERPENDICULAR FROM A POINT TO A LINE

As shown in figure 2-2-20, to lay out a perpendicular from a point to a line using a divider, lightly prick punch the point, C, then swing any arc from C which will intersect the line AB, and prick punch the intersections D and E as shown in the figure. With D and E as centers, scribe two arcs, which intersect at a point such as F. Place a straightedge on points C and F. The line drawn along this straightedge from point C to line AB will be perpendicular (90°) to the line AB.

LAYING OUT A CIRCLE WITH A DIVIDER OR WITH TRAMMEL POINTS

To lay out a circle with a divider, set the divider at the desired radius, using a rule as shown in figure 2-2-21. Note that the 3-inch radius being set here is being taken away from the end of the rule. This reduces the chance of error, as each point of the dividers can be set on a graduation.

Place one leg of the divider at the center of the proposed circle, lean the tool in the direction it will be rotated, and rotate it by rolling the knurled handle between your thumb and index finger (fig. 2-2-22).

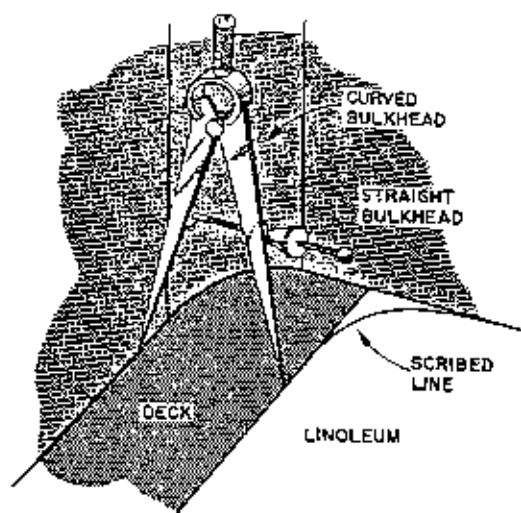


Figure 2-2-19.—Scribing a line to fit linoleum to a curved surface.

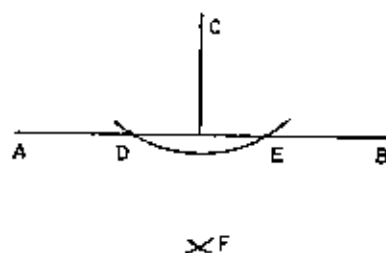


Figure 2-2-20.—Laying out a line perpendicular to a line.

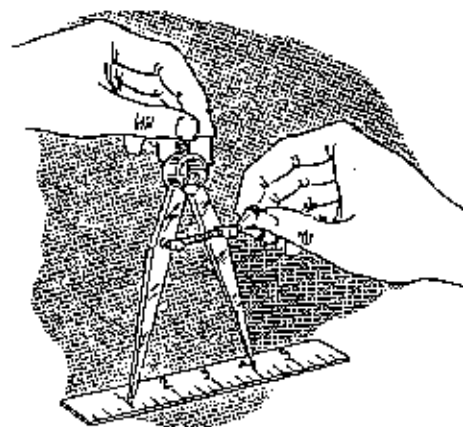


Figure 2-2-21.—Setting a divider to a desired radius.

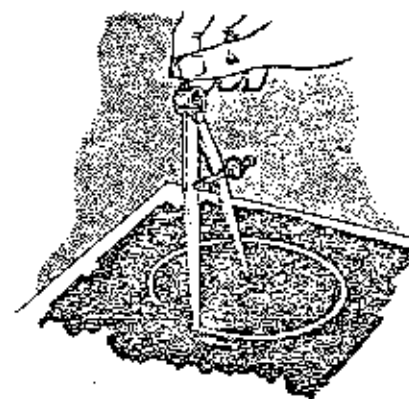


Figure 2-2-22.—Scribing a circle with a divider.

When setting trammel points, shown in figure 2-2-23, follow the same directions as for a divider, but use a steel tape or rule long enough to provide the larger radii that the trammel points can handle.

To lay out a circle with trammel points, hold one point at the center, lean the tool in the direction you propose to move the other point, and swing the arc or circle as shown in figure 2-2-23.

To transfer a distance measurement with trammel points, hold one point as you would for laying out a circle, and swing a small arc with the other point opened to the desired distance.

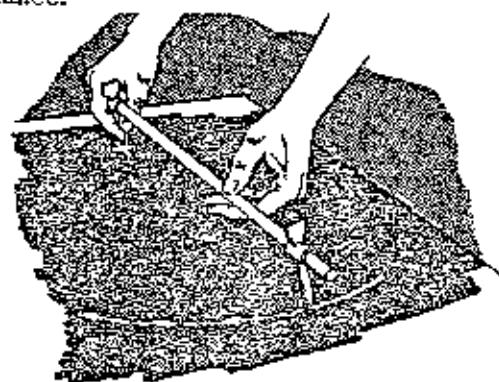


Figure 2-2-23.—Scribing a circle with trammel points.

PRICK PUNCHING THE INTERSECTION OF TWO LAYOUT LINES

To make the intersection of two layout lines, bring the point of the prick punch to the exact point of intersection and tap the punch lightly with a hammer. If inspection shows that the exact intersection and the punchmark do not coincide, as at A in figure 2-2-24, slant the punch as shown at B and again strike with the hammer, thus enlarging the punchmark and centering it exactly. When the intersection has been correctly punched, finish off with a light blow on the punch held in an upright position. C shows the corrected punchmark.

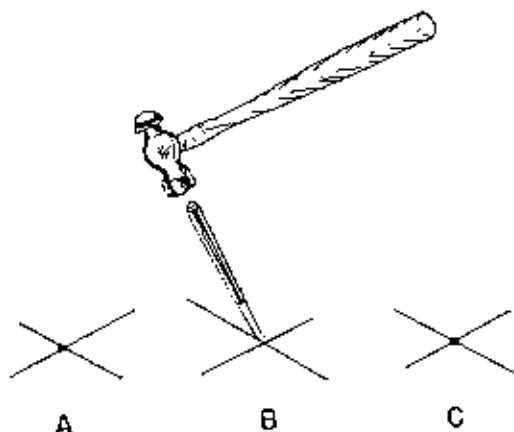


Figure 2-2-24.—Marking the intersection of lines with a prick punch.

LAYOUT WITH DIVIDER AND PRICK FOR A LARGE HOLE

Where exactness is required in locating a hole for drilling, make a layout and drill a pilot hole to pilot or guide the final size drill. In general, as drill sizes increase and the thickness of the web at the point of the drill increases, a pilot hole becomes more of a necessity. The web of a drill, as shown at (A) in figure 2-2-25, is the solid center of the point extending the length of the flutes. As the web does not actually drill and remove chips, a pilot hole is necessary for accurate drilling, both to remove the metal in this area, and to provide a true path for the larger drill to follow. (See fig. 2-2-25B.) The accuracy with which the pilot hole is located and drilled determines, in part, the accuracy of the location of the final or "size" hole.

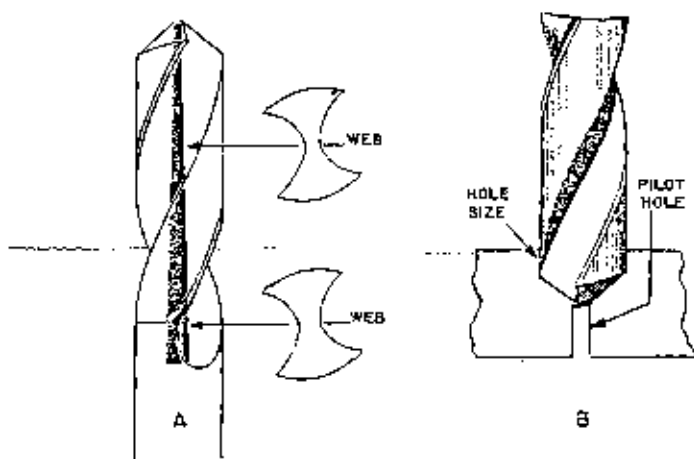


Figure 2-2-25.—Drilling a large hole.

To lay out a hole for accurate drilling, first apply layout dye sparingly to the surface to be laid out. Then place one leg of the divider in the prick punchmark which located the center of the hole and scribe a circle the size of the hole to be drilled. With the same center, scribe

another smaller circle (called the pilot-hole proof circle), the diameter of which is equal to the diameter of the pilot drill. (See fig. 2-2-26A.) In figure 2-2-26, the size of the pilot hole has been greatly exaggerated compared to the pilot-hole size which would actually be used for the final-hole size shown. This is done only to clarify the illustration. Then, as shown in figure 2-2-26B prick punch both circles along their circumferences to complete the layout. In figure 2-2-26C, the pilot hole has been drilled to its layout line as indicated by the half prick punchmarks that remain on the pilot-hole proof circle.

PUNCH MATING PARTS WITH A CENTER PUNCH FOR REASSEMBLY

Before taking a mechanism apart, make a pair of center punchmarks in one or more places to help in reassembly. To do this, select places, staggered as shown in figure 2-2-27, where matching pieces are joined. First clean the places selected. Then scribe a line across the joint and center punch the line on both sides of the joint, with single and double marks as shown to eliminate possible errors. In reassembly, refer first to the sets of punchmarks to determine the approximate position of the parts. Then line up the scribed lines to determine the exact position.

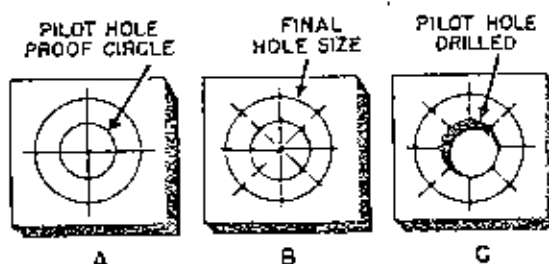


Figure 2-2-26.—Laying out a hole for accurate drilling.

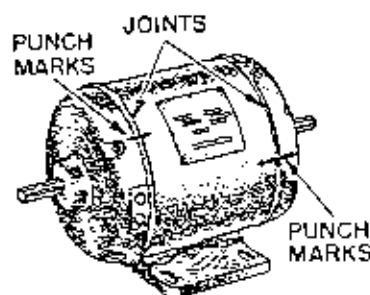


Figure 2-2-27.—Prick-punching mating parts of a mechanism.

TESTING, CHECKING, AND SETTING

Many of the measuring and layout tools used by mechanics also are used for inspecting a finished product or partly finished product. Inspection operations consist of testing, checking, and setting of a piece of work. This is accomplished by comparing the dimensions or shape of a piece of work with the required dimensions given on a drawing or sketch. There are many specialized tools especially made for checking certain jobs. It is not the purpose however, of this section to give detailed explanations of special tools, but rather to show how to use some of the more common handtools for testing, checking, and setting.

ADJUSTING A SLIDING T-BEVEL TO A DESIRED SETTING

To adjust a sliding T-bevel to a desired setting, loosen the blade screw, at the round end of the handle, just enough to permit the blade to slide along its slot and to rotate with slight friction.

To set the blade at a 45° angle, hold the handle against a framing square, as shown in figure 2-3-1A, with the blade intersecting equal graduations on the tongue and blade of the square. Or: hold the bevel against the edges of a 45° drafting triangle as shown in figure 2-3-1B. When using drafting triangles for setting a sliding T-bevel, different size triangles must be used for each different setting. A 45° angle can also be set by using the squaring head of a combination set as shown in figure 2-3-1C.

A sliding T-bevel can be set to any desired angle by using a protractor. Loosen the blade screw as before, and hold the bevel with its blade passing through the graduation selected, and the center of the protractor as shown at (D) in figure 2-3-1.

TESTING THE TRUENESS OF A CHAMFER OR BEVEL WITH A SLIDING T-BEVEL

To test a chamfer or bevel for trueness, set the T-bevel to the required angle, and hold the handle to the working face of the stock being tested. Face a source of light, and with the blade brought into contact with the surface to be tested, pass the blade along the length of the surface. (See fig. 2-3-2.) The appearance of light between the blade and the surface of the stock indicates where the angle is not correct. Figure 2-3-2 indicates the checking of a bevel, but testing the trueness of a chamfer is accomplished in the same way.

TESTING TRUENESS OF A 45° ANGLE WITH A COMBINATION SQUARE

To test trueness of 45° angles with a combination square, hold the body of the square in contact with one surface of the 45° angle, and move the blade into contact with the other. (See

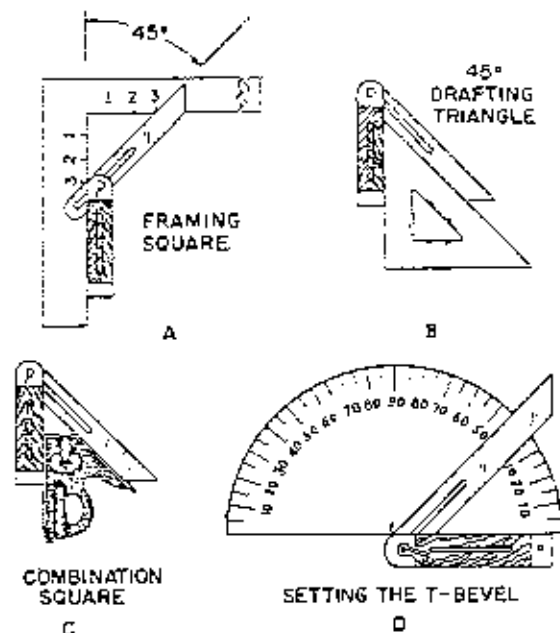


Figure 2-3-1.—Adjusting a sliding T-bevel to a desired setting.

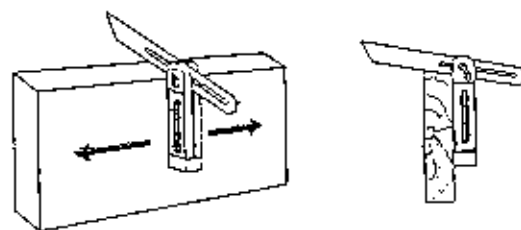


Figure 2-3-2.—Testing the trueness of a bevel.

fig. 2-3-3.) In making this test, have the square between yourself and the source of light. If the angle is a true 45° angle, no light will be visible between the blade and the surface of the work.

TESTING TRUENESS OF A 90° ANGLE WITH A COMBINATION SQUARE

To test trueness of 90° angles with a combination square, hold the body of the square in contact with one surface of the 90° angle and bring the blade into contact with the other. (See fig. 2-3-4.) In making this test, have the square between yourself and a good source of light. If the angle is a true 90° angle, no light will be visible between the blade and the surface of the work.

SETTING A SURFACE GAGE FOR HEIGHT

To set a surface gage for height, first wipe off the top of a layout table or surface plate and the bottom of the surface gage. Use either a combination square or a rule with rule holder to get the measurement. A rule alone cannot be held securely without wobbling and conse-

quently an error in setting generally results. Because a combination square is generally available, its use for setting a surface gage is explained in this section.

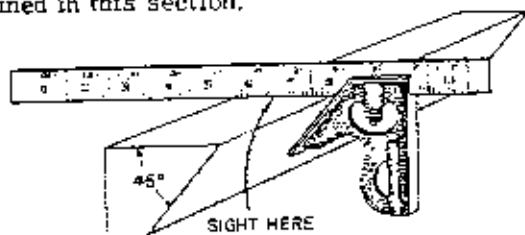


Figure 2-3-3.—Testing the trueness of a 45° angle with a combination square.

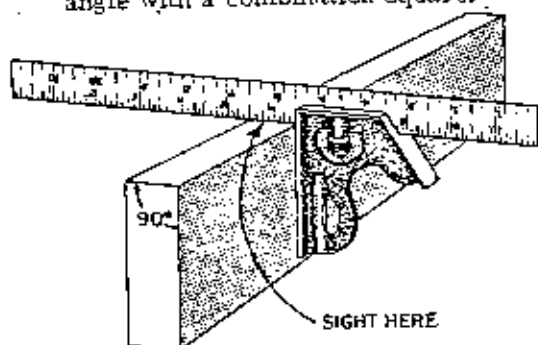


Figure 2-3-4.—Testing the trueness of a 90° angle.

Place the squaring head of a combination square on a flat surface as shown in figure 2-3-5, and secure the scale so that the end is in contact with the surface. Move the surface gage into position and set the scriber to the approximate height required, using the adjusting clamp that holds the scriber onto the spindle. Make the final adjustment for the exact height required (4 1/2 inches in this case) with the adjusting screw on the base of the gage.

LEVELING AND PLUMBING EQUIPMENT WITH A CARPENTER'S LEVEL

To level a piece of equipment, such as the workbench in figure 2-3-6, set a carpenter's level on the bench top parallel to the front

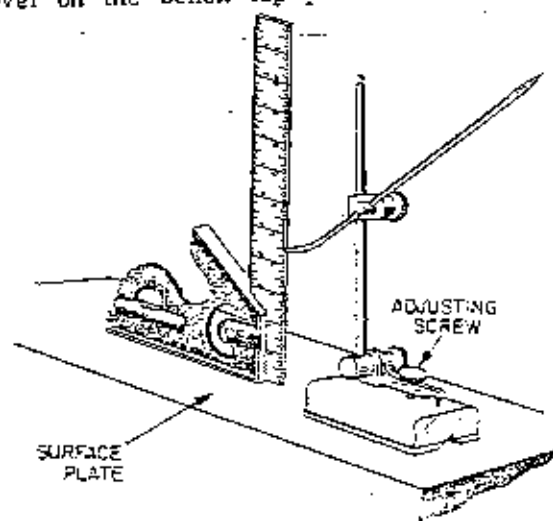


Figure 2-3-5.—Setting a surface gage to height.

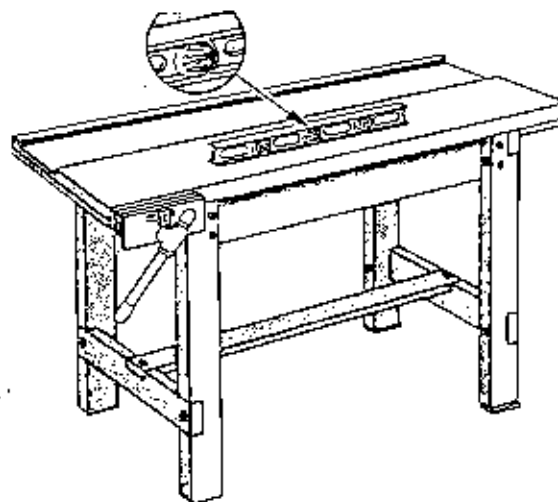


Figure 2-3-6.—Leveling a bench.

edge of the bench. Notice that the level may have as many as three or more pairs of glass vials. Regardless of the position of the level, always watch the bubble in the bottom vial of a horizontal pair. Shim or wedge up the end of the bench that will return that bubble to the center of its vial. Recheck the first position of the level before securing the shims or wedges.

To plumb a piece of equipment, such as the drill press shown in figure 2-3-7, place the level on the side and on the front of the main column of the press. Figure 2-3-7 shows the level on the side. Use shims as necessary to bring the bubble in the lower vial of either pair of the horizontal vials to the center in each case.

USING A PLUMB BOB

The plumb bob is used to determine true verticality. It is used in carpentry when erecting vertical uprights and corner posts of framework. Surveyors use it for transferring and lining up points.

To locate a point which is exactly below a particular point in space, secure the plumb bob string to the upper point, such as A in figure 2-3-8. When the plumb stops swinging, the point as indicated at B in the illustration, will be exactly below A.

To plumb a structural member, or an electrical conduit, as shown by figure 2-3-9, secure the plumb line A so that you can look at both the line and piece behind the line. Then, by sighting, line up the member or conduit with the plumb line.

If this cannot be done, it may be necessary to secure the plumb line at some point such as B, and then measure the offset from the line to the piece at two places so that, for example, C and D in figure 2-3-9 are equal. If the distances between C and D are not equal, adjust the structural member or conduit until they are.

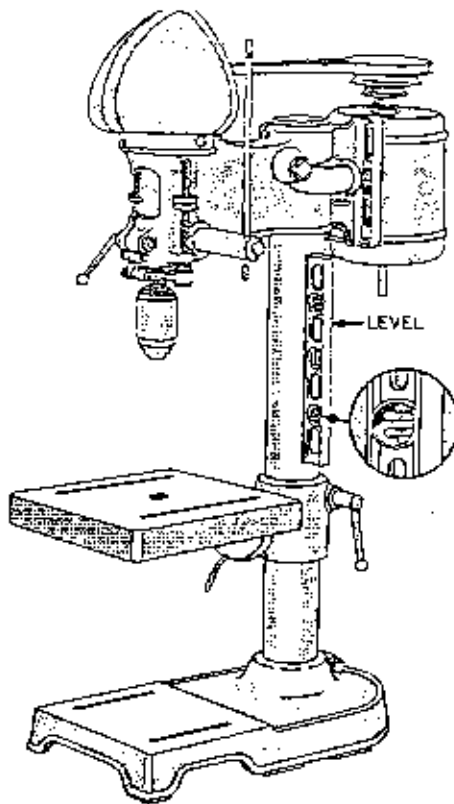


Figure 2-3-7.—Plumbing a piece of equipment with a level.

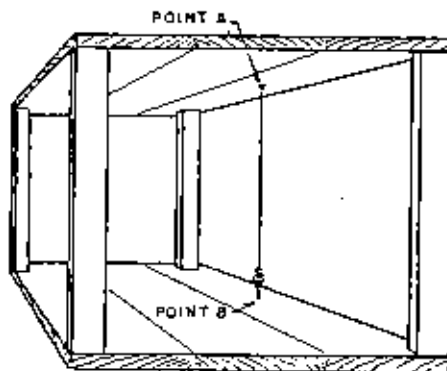


Figure 2-3-8.—Locating a point with a plumb bob.

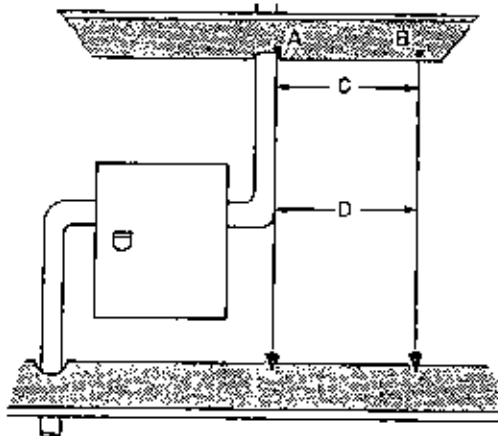


Figure 2-3-9.—Plumbing a structural member with a plumb bob.

USING A THICKNESS GAGE FOR CHECKING CLEARANCE BETWEEN SURFACES

To check clearance between surfaces, first clean the surfaces where the check will be made. Then insert blades of the thickness gage (fig. 1-1-86) into the clearance between the surfaces until a blade is found that enters with a slight drag. Then read the gage as follows.

In figure 2-3-10, the thickness gage leaf and the piston ring will both fit into the ring groove

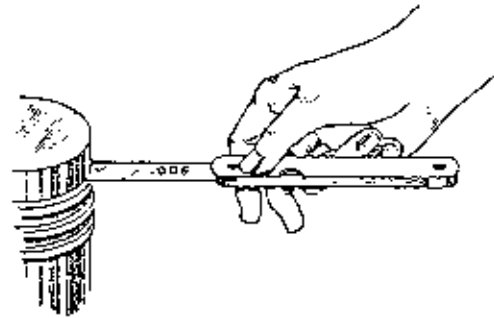


Figure 2-3-10.—Checking piston ring clearance with a thickness gage.

in the piston at the same time. Therefore, the number that appears on that leaf of the gage represents the number of thousandths of an inch of clearance there is between the piston ring and the side of the groove in the piston. All thickness gages have the thickness given on each leaf as a decimal part of an inch, such as 0.003", or 0.025". When necessary, two or more leaves can be used together for larger clearances. Keep the leaves clean and handle them with care so as not to cause damage to their edges or polished surfaces.

TESTING A SURFACE FOR FLATNESS

To test a surface for flatness, carefully clean it and remove all burrs. Then place the surface of the object on a flat area such as the surface plate in figure 2-3-11. Any rocking motion that is apparent will indicate a variance from flatness of the piece being tested.

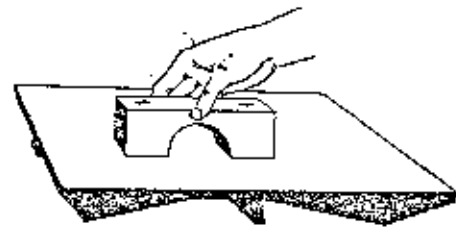


Figure 2-3-11.—Testing a surface for flatness.

To determine how much variation there is from flatness—and where it is—you can insert leaves of a thickness gage to determine the amount of variation of flatness. Remember to add the thickness of all leaves together to get the total variation. (See fig. 2-3-12.)

For very fine work, lightly coat the surface plate with prussian blue (bearing blue) and move the piece being tested across the blue surface. (See fig. 2-3-13.) The low spots on the surface

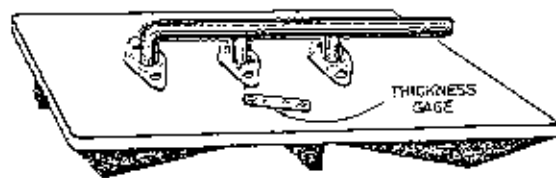


Figure 2-3-12.—Checking the conformity of a flat surface.

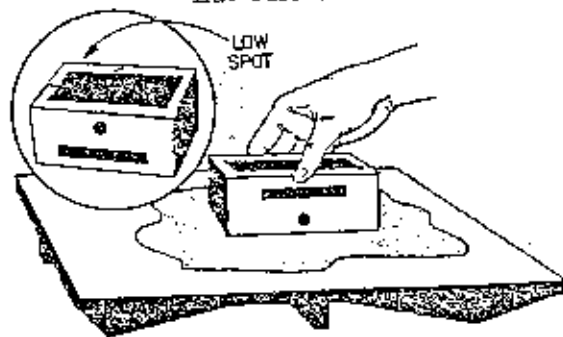


Figure 2-3-13.—Using prussian blue to aid in testing a flat surface.

being tested will not take the blue; the high spots will. See insert in figure 2-3-13.

A surface also may be tested for flatness with a straightedge. To do this, clean the surface thoroughly and hold the straightedge on the surface in several places as you look toward a source of light. The light showing between the surface being tested and the straightedge will reveal the low spots.

SETTING A COMBINATION FIRM JOINT CALIPER WITH A RULE

To set a combination firm joint caliper with a rule, when the legs are in position for outside measurements, grasp the caliper with both hands, as shown in figure 2-3-14A, and adjust both legs to the approximate setting. By adjusting both legs, the shape of the tool will be approximately symmetrical. Thus it will maintain its balance and be easier to handle.

Check this approximate setting and subsequent adjustments to the setting, as shown in 2-2-14B by resting one leg on the end of the rule. Sight squarely across the other leg at the graduations on the rule to get the exact setting required.

If it is necessary to decrease the setting, tap one leg of the caliper, as shown in figure 2-3-15A. If it is necessary to increase the setting, tap one leg of the caliper, as shown in figure 2-3-15B. In both illustrations the arrow indicates the change in setting that will take place.

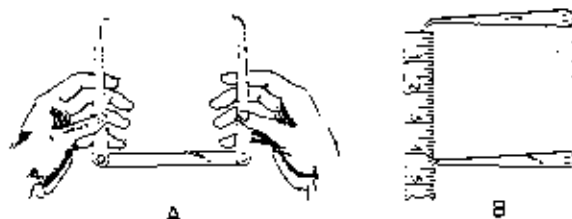


Figure 2-3-14.—Setting a combination firm joint caliper.

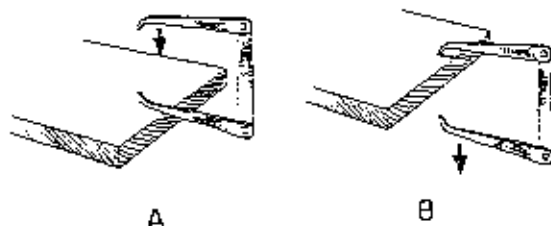


Figure 2-3-15.—Decreasing and increasing the setting of a firm joint caliper.

When the caliper is set for inside measurements, the same directions for adjusting the setting apply. Figure 2-3-16 shows how the end of the rule and one leg of the caliper are rested on the bench top so that they are exactly even with each other when the reading is taken.

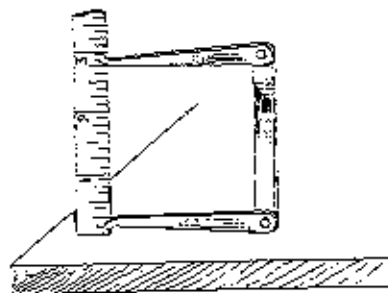


Figure 2-3-16.—Setting a combination firm joint caliper for inside measurements.

SETTING OUTSIDE AND INSIDE SPRING CALIPERS WITH A RULE

To set a particular reading on an outside spring caliper, first open the caliper to the approximate setting. Then, as shown in figure 2-3-17, place one leg over the end of the rule, steadying it with index finger. Make the final setting by sighting over the other leg of the caliper, squarely with the face of the rule at the reading, and turning the knurled adjusting nut until the desired setting is obtained. To set an inside spring caliper to a particular reading, place both caliper and rule on a flat surface as shown in figure 2-3-18. The rule must be held squarely or normal (90° in both directions) to the surface to ensure accuracy. Adjust the knurled adjusting nut, reading the setting on the rule with line of sight normal to the face of the rule at the reading.

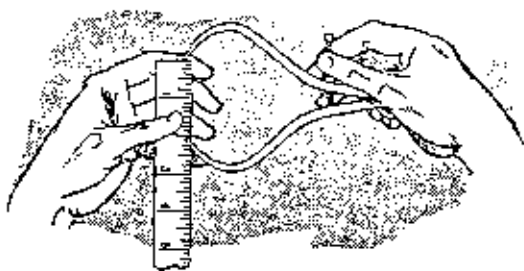


Figure 2-3-17.—Setting an outside spring caliper.

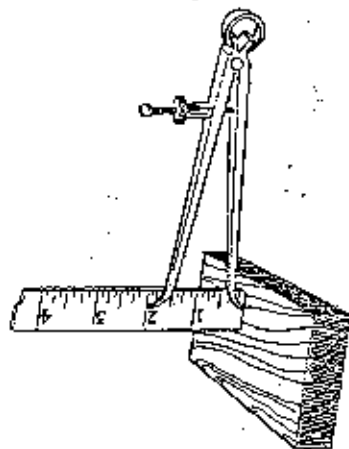


Figure 2-3-18.—Setting an inside spring caliper.

TRANSFERRING MEASUREMENTS FROM ONE CALIPER TO ANOTHER

To transfer a measurement from one spring caliper to another, hold the calipers as shown in figure 2-3-19. Note that one of the man's fingers is extended to steady the point of contact of the two lower caliper legs. In this figure the inside caliper is being adjusted to the size of the outside caliper. As careful measurements with calipers depend on one's sense of touch, which is spoken of as "feel," calipers are best

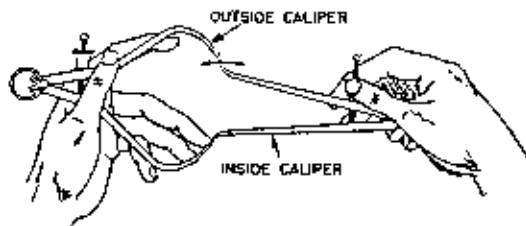


Figure 2-3-19.—Transferring a measurement from an outside to an inside caliper.

held lightly. When you notice a slight drag, the caliper is at the proper setting.

SETTING A DIVIDER TO REQUIRED DIMENSIONS

In setting a divider to a dimension on a scale, the usual procedure is to locate one point in one of the inch graduations of the rule and

turn the knurled adjusting nut or screw so that the other point falls easily into the desired graduation. (See fig. 2-3-20.) Make certain the points of the divider are not blunt.

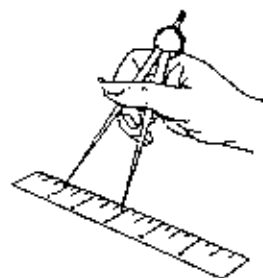


Figure 2-3-20.—Setting a divider using a rule.

Most vernier calipers, except the larger sizes, have two center points similar to prick punchmarks. These are particularly useful in setting a divider to exact dimensions. One center point will be found near the zero end of the scale on the rule. The other point is in line with the first and to the left of the zero on the vernier scale. (See fig. 2-3-21.)

Set and secure the desired setting on the vernier caliper and adjust the divider until both points readily enter the center points on the vernier caliper as in figure 2-3-21.

TRANSFERRING A MEASUREMENT TO AN OUTSIDE MICROMETER

To transfer a measurement from an inside spring caliper, a telescoping gage, or an inside

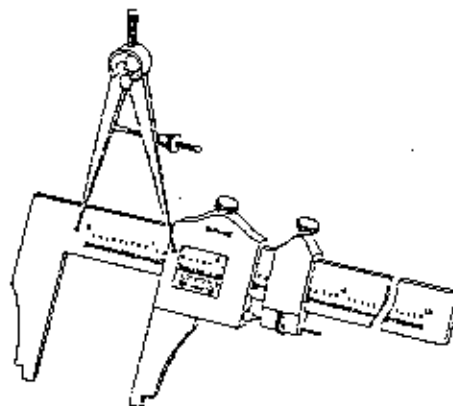


Figure 2-3-21.—Setting a divider with a vernier caliper.

micrometer caliper to an outside micrometer caliper as shown in figure 2-3-22, proceed as you would to measure the outside diameter of round stock. In effect, you are simply measuring the setting of one of these tools with the outside micrometer. You proceed as you would in calipering round stock because the contact area is small and the contact pressure on the micrometer must be kept at a minimum. Use the ratchet stop, if the micrometer has one, to provide the correct pressure.

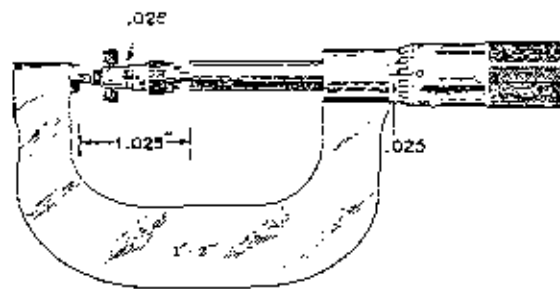


Figure 2-3-22.—Transferring a measurement from an inside to an outside micrometer caliper.

The transfer of a measurement from the inside to the outside micrometer calipers can be a check on their accuracy, as both readings should be exactly the same. If they are not, first check the zero setting on each according to the manufacturer's instructions and make any necessary corrections. Then take a reading on a known dimension with the outside caliper such as on a gage block. This gage block must be somewhere between 1" and 2" in size, since the micrometer shown has a 1" to 2" range. If this reading does not check out, the threads on the spindle and in the sleeve of the outside micrometer are probably worn. This requires returning the micrometer to the manufacturer for repairs.

If the gage test shows the outside micrometer caliper to be correct, the trouble is likely with the threads on the inside micrometer caliper. It, also, must be sent to the manufacturer for repairs.

CHECKING HEIGHT WITH A DIAL INDICATOR

To check height with a dial indicator, support the indicator with a surface gage, as shown in figure 2-3-23. This figure shows the surface

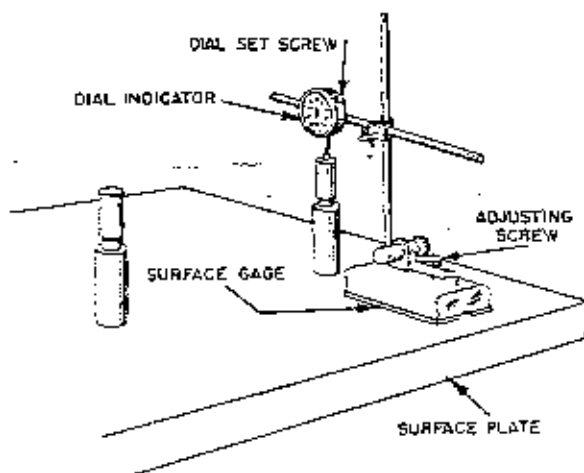


Figure 2-3-23.—Checking the difference in heights of objects with a dial indicator.

gage and two objects resting on a surface plate. With the adjusting screw on the surface gage, move the indicator down into contact with the first object and secure the setting when the hand

has moved about five-thousandths on the dial. Release the dial setscrew that is at the edge of the dial, rotate the dial to align the zero with the hand, and retighten the setscrew. Then, without changing any of the adjustments, carefully slide the surface gage along the surface plate to take a dial indicator reading on the other object, or move the other object under the spindle of the dial indicator. The plus or minus reading on the dial will indicate the number of thousandths of an inch that the two objects differ in height.

If the second object being checked is more than five-thousandths of an inch shorter than the first, reset the dial indicator lower to get the difference reading.

TESTING THE TRUENESS OF SHAFTS AND WHEELS WITH A DIAL INDICATOR

To test the trueness of a shaft between centers (fig. 2-3-24), set up a dial indicator on a surface

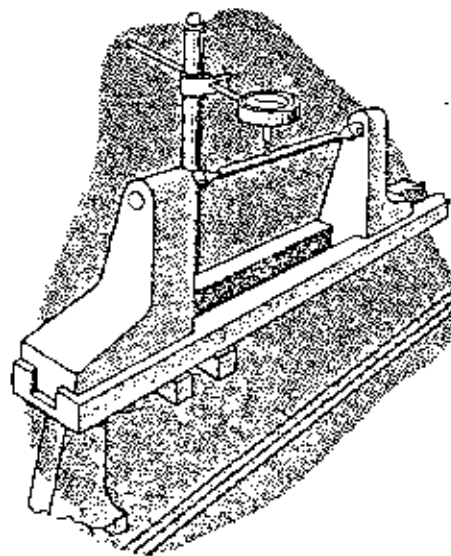


Figure 2-3-24.—Testing the trueness of a shaft between centers.

gage so that the contact point of the spindle rests on the shaft near the middle. Now turn the shaft slowly as you watch the needle on the dial. A bent shaft, as it turns, will cause the spindle to move up or down. This motion is registered on the dial which is calibrated in one-thousandths of an inch. To read the total "runout" of the shaft, which means the amount it is bent out of line, loosen the dial setscrew that secures the rim of the indicator case and adjust the dial so that the zero coincides with the needle at one end of its travel. Then turn the shaft and take the reading at the other end of the needle's travel. This reading will indicate the number of thousandths of an inch the shaft is out of true, and it will enable you to find the high side as the shaft rotates.

To test the trueness of a wheel, gear, or sheave, set up the dial indicator so that its spindle is parallel to the shaft on which the wheel is mounted, and so that the tip of the spindle bears on the side of the wheel near its

outer edge. As the wheel is rotated, the needle will indicate the runout in thousandths of an inch and enable you to find the place where it is at the maximum. (See fig. 2-3-25.)

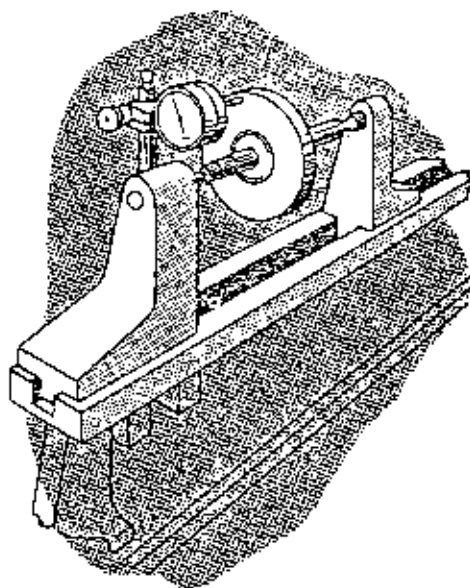


Figure 2-3-25. —Testing the trueness of a wheel.

WOODCUTTING OPERATIONS

One of the most important operations you will perform with wood is the proper laying out and cutting of stock lumber. Laying out is explained in an earlier section of this course.

It is important to determine at the beginning that the quality of stock fits your needs. Examine the stock for knots and checks, and lay out the job so that the imperfections will be cut away or will appear on the back side or underneath side where they will not be seen.

Check the stock to be certain that it is of proper size to ensure the required thickness and width of the piece you need. When laying out the job, keep in mind that there should be as little waste of material as possible.

USING A HAND SAW

To saw across the grain of the stock, use the crosscut saw, and to saw with the grain, use a rip saw. Study the teeth in both kinds of saws so you can readily identify the saw that you need.

Place the board on a saw horse (fig. 2-4-1), or some other suitable object. Hold the saw in the right hand and extend the first finger along the handle as shown in the figure. Grasp the board as shown and take a position so that an imaginary line passing lengthwise of the right forearm will be at an angle of approximately 45 degrees with the face of the board. Be sure the

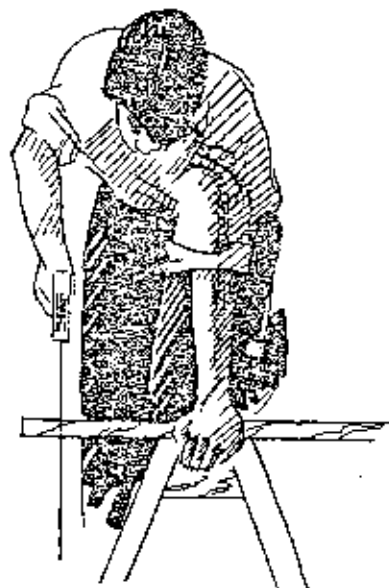


Figure 2-4-1. —Proper position for sawing a board to size.

side of the saw is plumb or at right angles with the face of the board. Place the heel of the saw on the mark. Keep the saw in line with the forearm and pull it toward you to start the cut.

To begin with, take short, light strokes, gradually increasing the strokes to the full length of the saw. Do not force or jerk the saw. Such procedure will only make sawing more difficult. The arm that does the sawing should swing clear of your body so that the handle of the saw operates at your side rather than in front of you.

Use one hand to operate the saw. You may be tempted to use both hands at times, but if your saw is sharp, one hand will serve you better. The weight of the saw is sufficient to make it cut. Should the saw stick or bind, it may be because the saw is dull and is poorly "set." The wood may have too much moisture in it, or you may have forced the saw and thus have caused it to leave the straight line.

Keep your eye on the line rather than on the saw while sawing. Watching the line enables you to see just the moment that the saw tends to leave the line. A slight twist of the handle, and taking short strokes while sawing, will bring the saw back. Blow away the sawdust frequently so you can see the layout line.

Final strokes of the cut should be taken slowly. Hold the waste piece in your other hand so the stock will not split when taking the last stroke.

Short boards may be placed on one sawhorse when sawing. Place long boards on two sawhorses, but do not saw so your weight falls between them or your saw will bind. Place long boards so that your weight is directly on one end of the board over one sawhorse while the other end of the board rests on the other sawhorse.

Short pieces of stock are more easily cut when they are held in a vise. When ripping short stock it is important that you keep the saw from sticking, so it may be necessary to take a squatting position. The saw can then take upward direction and thus work easily. When ripping long boards it will probably be necessary to use a wedge in the saw kerf to prevent binding (See fig. 2-4-2.)

USING PORTABLE CIRCULAR SAW

When you use a portable electric circular saw for cutting stock to size, make layout lines the same as if you were using a hand saw. Adjust the depth of the saw cut, never allowing

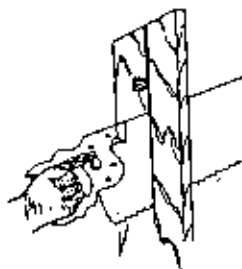


Figure 2-4-2.—Using a wedge in a saw kerf to prevent binding.

more than 1/4 inch of the saw blade to protrude through the material. When crosscutting (across the grain) turn the ripping guide up out of the way. Start the saw by pressing the switch in the handle. Allow the saw to run for a few seconds to see that it is operating properly.

NOTE: You should never use a power saw unless you have been instructed in its use by a proficient operator.

Place the stock to be cut on sawhorses or other support in such a way that it will not change its position while being cut. Accidents might occur when the power saw is used to cut short pieces that might slip or that are hard to hold. Hold the board with one hand, and guide the saw along the layout line with the other.

Somewhere at the front of the shoe of the saw is a line which tells you the cut line of the saw blade. By keeping this line traveling on the pencil mark you will know the cut will be true. If you find that you are traveling off the line, do not attempt to force the blade back into line again. It is best to back out the blade and make a new approach.

At the start of the cut, be sure the blade is not making contact with the work. Rest the tool on the work, line up the cut guide with the layout line, and when the blade has attained full speed, start cutting. Wood does not have uniform density, therefore, the cut will be easier in some places than in others. This is especially true when you are cutting through a knot in the wood. If at any time the saw begins to labor, slow up the feed pressure. It is not advisable to release

the switch when the blade stalls or approaches a stall; instead, back the blade out from the cut until the saw resumes full speed, and continue the cut. Ease up on the feed pressure to compensate for the additional density through which you are cutting.

Never work with the tool resting on the portion of the work which is being cut off. If you do this, the tool will have no support at the end of the cut. Always position the tool on the main side of the cut. Position yourself where your body is out of the line of cut.

The cut itself should be made just outside of the layout line. Remember that the saw cut (kerf) has width, and that if you cut exactly on the line, you will be reducing the dimension you need by at least half the width of the kerf.

When ripping a board with a saw that is equipped with a rip guide, it is not necessary to make a layout line. Set the rip guide to the desired width of the board as shown in figure 2-4-3. Feed the saw into the material in the same manner as when crosscutting. Push the saw forward so that the ripping gage will slide along the edge of the board. Observe the same precautions in handling the saw as in crosscutting.

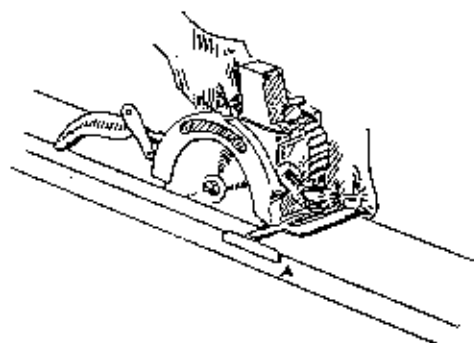


Figure 2-4-3.—Ripping with a portable circular, using a ripping guide.

USING A RADIAL ARM SAW (CUT OFF)

When using a radial arm saw for cutting stock to size, it is important that you follow the manufacturer's manual in making the adjustments of the saw and securing the locks. Review the information of radial arm saws in section I part 2 of this course if you have any doubt as to what adjustments must be made. While the relationship of parts is basically the same on all saws, adjustment procedures may vary, so study the literature that comes with the machine you are operating.

To cut a board to size, first do the crosscutting that is necessary. Make the layout lines the same as for any other job. Before placing the board on the table of the saw, start the saw and let it come up to operating speed, and pass the saw back and forth through the line of cut to make sure it operates properly.

Place the board to be cut on the saw table against the guide fence and make sure the layout line is in line with the line of cut of the saw. Place your left hand to the left of the saw blade travel. (See fig. 2-4-4.) Turn on the switch and pull the blade gradually through the work. Then return the blade to the starting position.



Figure 2-4-4.—Crosscutting, using a radial arm saw.

The cut is complete when the blade has passed across the board width, but the operation is not complete until you have returned the blade to the rear of the arm travel. This is important. ALWAYS RETURN THE BLADE TO THE STARTING POSITION.

When ripping a board to size, push the work into the blade rather than pull the blade through the work. Set the saw blade parallel to the guide fence. Set the blade a distance from the guide fence equal to the width of the cut that you wish to make and lock the saw in position. (See fig. 2-4-5.)

Never feed the work in the direction of rotation of the blade. You must always feed against the rotation. Most saws are marked with arrows and warnings to help you remember correct feed direction for rip cuts.

One edge of the work rides against the fence so it is important that the blade (in rip position) and the fence be parallel. If binding occurs it is a good sign that the blade is not in parallel alignment with the fence.

Feed the work into the saw at a moderate speed, but not so fast that the saw will stall. Keep your hand that is doing the feeding well away from the cutting area. Use push sticks (fig. 2-4-6) to feed the work into the saw when you near the end of the cut. When the cut is complete, turn off the switch, then remove the work from between the blade and fence. Never do this while the blade is turning.

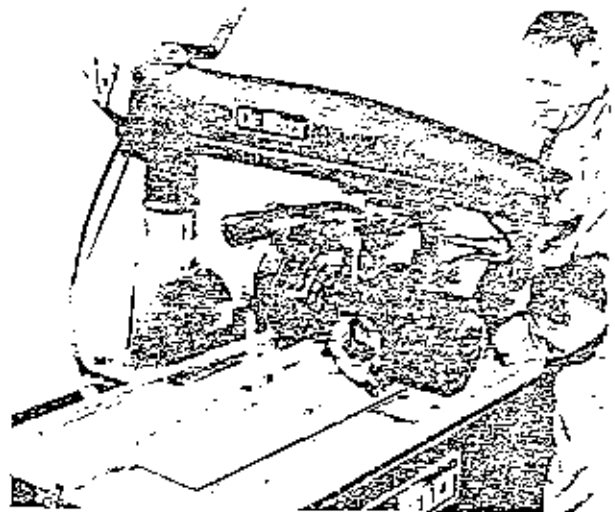


Figure 2-4-5.—Ripping, using a radial arm saw.

ASSEMBLING AND ADJUSTING A PLANE FOR CUTTING

To assemble the plane iron or blade and the plane iron cap for cutting, first hold the cap and blade as shown in figure 2-4-7A. Notice that the bevel on the blade is on the side opposite the cap side. When the head of the cap screw has dropped through the hole in the blade, slide it down the slot in the blade to the position shown

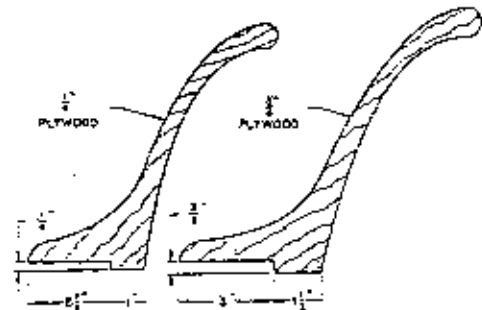


Figure 2-4-6.—Push stick for ripping.

in figure 2-4-7B. Then rotate the cap to the position shown in figure 2-4-7C, keeping the curved end of the cap well away from the cutting edge of the blade. Now slowly and carefully move the cap toward the cutting edge of the blade until it is about 1/32" away from the cutting edge as shown in figure 2-4-7D.

In part I section 1 figure 1-1-45A you will see the 1/32" setback from the end of the blade to the cap. The purpose of the cap is to curl the chips as they are cut off the wood by the cutting edge of the blade. This cap is sometimes called a chip breaker. The cap is fitted properly to the blade in figure 1-1-45A. Figure 1-1-45B shows a cap which has been improperly ground and therefore does not fit correctly.

This will cause chips to become lodged between the blade and the cap. The improper fit may be corrected by filing or grinding the cap just behind its forward edge. In figure 1-1-45C the chip is being properly curled by the cap. Chips are curled so that they take a minimum of room, tend to break off as they increase in size, are

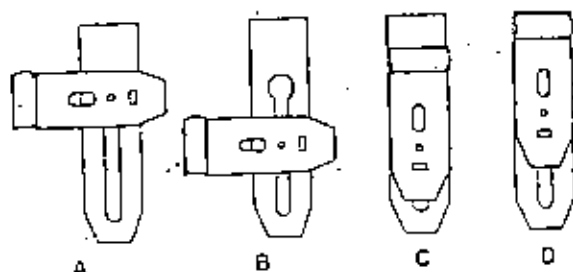


Figure 2-4-7.—Assembling a plane iron and cap for cutting.

less likely to foul the cap when coming out of the plane, and are more easily disposed of when swept from the bench top or the deck.

To complete assembly, and to adjust a plane for use, refer to figure 1-1-44. Place the assembled plane iron and cap in place, as shown in figure 1-1-44 (A and B), and be very careful to keep its delicate cutting edge from coming in contact with the other metal parts of the plane. The lug, shown in figure 1-1-44A, at the lower end of the lateral adjustment lever, must enter the slot in the blade. The upper end of the "Y" adjustment must enter the rectangular hole in the plane iron cap. The lever cap screw shown in figure 1-1-44C is used for adjusting the tension of the lever cap bearing on the plane iron cap. When the lever cap lever is down, as shown in 1-1-44C, and the lever cap is loose in its place, tighten the lever cap screw a quarter or a half turn at a time until the looseness disappears.

To adjust the plane for use (which means having the blade protruding through the bottom of the plane the proper amount, and having its edge parallel to the bottom of the plane), refer to figures 1-1-46 and 1-1-47. As you sight along the bottom of the plane, turn the adjusting nut until you can just barely see the blade protruding through the bottom of the plane. Figure 1-1-46 (B and C) shows you (greatly exaggerated) what to look for. The three views in figure 1-1-47 indicate how either one corner or the other of the plane iron can be withdrawn by moving the lateral adjusting lever from left to right. The final position of the lateral adjusting lever is not important. What is important is to have the blade protruding evenly across the width of the bottom of the plane.

PLANING STOCK TO GIVEN DIMENSIONS

To plane stock to given dimensions, a stand-

ard procedure is recommended. You will generally start with a piece of square stock. Part II, section 3, of this course shows you the best methods for testing stock for squareness.

Figure 2-4-8 shows the six standard steps to follow in planing any stock to given dimensions; to get accurate results, follow carefully the procedures shown.

To plane a chamfer, as shown in figure 2-4-9A, first make the layout on both sides of the corner to be chamfered. Figure 2-4-9 (B and C) show these layout lines being made with a marking gage.

To plane the chamfer on an edge secure the stock in a vise, if possible, as shown in figure 2-4-10A. As you are planing to two layout lines, watch both lines carefully so that both lines are reached at the same time. Figure 2-4-10B shows an end view of planing a chamfer on an edge.

To plane a chamfer on the end of a piece of stock, secure the stock and plane as shown in figure 2-4-11. Notice carefully the angle at which the plane is being held. Move the plane according to the directional arrow shown in the figure, and work from left to right until the entire width of the stock has been chamfered. Layout lines are used as before.

To plane a bevel only one layout line is required due to the fact that the opposite edge of the stock serves as the other layout line. Plane the bevel as you would plane a chamfer, holding the stock in a vise.

To plane across end grain, figure 2-4-12A, hold the block plane at an angle so that the blade will make a shearing cut. Block-plane adjustments are basically the same as those for smoothing and jack planes. See figure 2-4-12B. To assemble a block plane, which has a cap similar to the lever cap on a smoothing plane but has no plane iron cap, insert the blade carefully into the body with the bevel up. This position of the plane iron is just opposite to the plane iron position in planes with lever caps. A block plane has a very low blade angle to facilitate planing across grain. If the plane-iron bevel were down, its heel would not permit the cutting edge to come into contact with the surface of the work.

To see how to prevent splitting the edge of the stock when planing across its end, refer to figure 2-4-13. At (A) the presence of the layout line indicates that the board has not yet been planed to its required width. The splitting that occurs is therefore in the scrap area. At (B) the end is first planed from one edge toward the middle and then from the other. No splitting ever takes place when the plane enters the cut, but does occur when it leaves the cut at the edge of the work. In this method it does not leave the cut at the edge. At (C) a bar clamp holds a piece of scrap stock in place to back up the job at one edge. Again splitting occurs, but in the scrap stock.

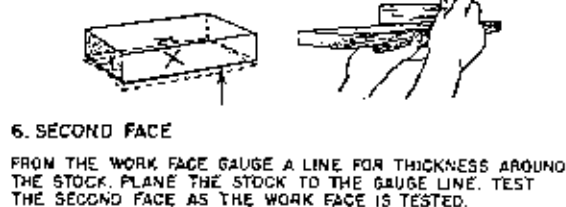
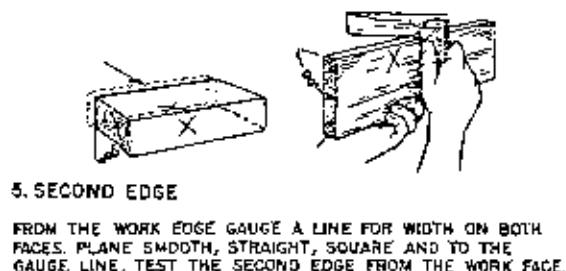
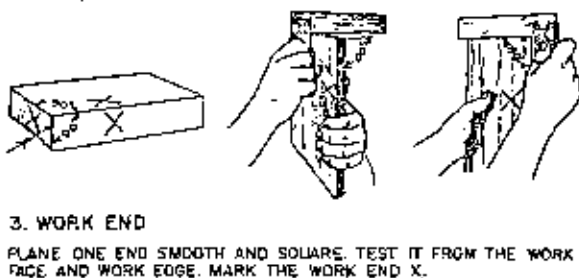
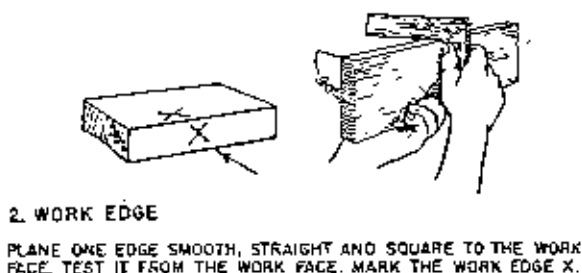
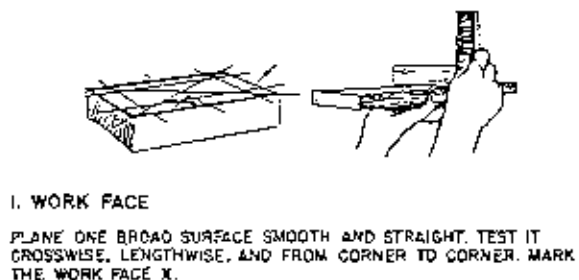


Figure 2-4-8.—Steps to follow in planing any stock to a given size.

USING A DRAWKNIFE (DRAWSHAVE) FOR ROUGHING OUT A CURVE

A drawknife is useful for roughing out a curve or any irregular surface in lumber. This is especially true where a large amount of waste material must be removed.

To use a drawknife, first make the layout lines on the stock material where they are needed. Clamp the stock in a vise or otherwise hold it securely. The drawknife is always pulled toward the operator with both hands and since, in most cases, you will be cutting both with and across the grain of the stock, it is advisable to work first on one side of the cut then the other. This procedure will lessen the chances of splitting the stock. Keep the bevel side of the blade up for ordinary work, and move one end of the blade slightly ahead of the other to give an oblique or sliding cut. This gives better control of the tool and enables you to cut to the layout line more easily.

After you have removed most of the excess material from the cut, use a woodrasp or sandpaper to smooth the cut even with the layout lines.

BORING HOLES IN WOOD

Boring holes is frequently necessary when

working with wood. It is important, therefore, that you know the proper procedures and the tools that are used for this job.

The auger bit is the tool that actually does the cutting in the wood; however, it is necessary that another tool be used to hold the auger bit and give you enough leverage to turn the bit. The tools most often used for holding the bit are the carpenter's brace, breast drill, push drill, and the drill press.

For accurate boring, first mark the location for the center of the hole by the intersection of two cross lines, or by a small hole made with an awl or other sharp-pointed tool. As the auger starts boring, be careful to keep it perpendicular to the surface (unless you are boring the hole at an angle). To see that the auger is boring square with the surface, step back a little, steadying the brace or drill with one hand, and sight; then move around and sight in another direction about at right angles to the first direction of sighting. A square may also be used to see if the bit is going straight. It is better for a beginner not to depend too much on the square, however, but to develop ability in sighting. Leaning the top of the auger slightly one way or another will change the direction of boring.

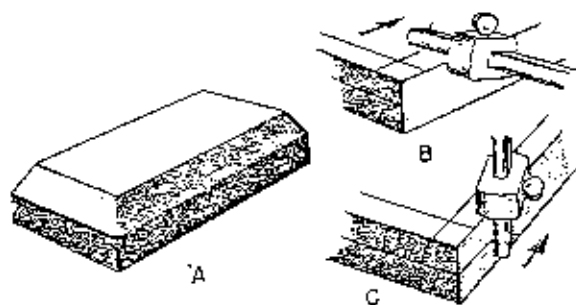


Figure 2-4-9.—Laying out for planing a chamfer.

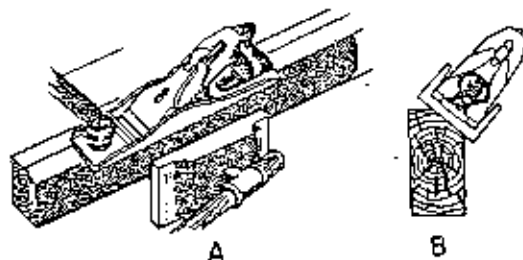


Figure 2-4-10.—Planing a chamfer on stock.

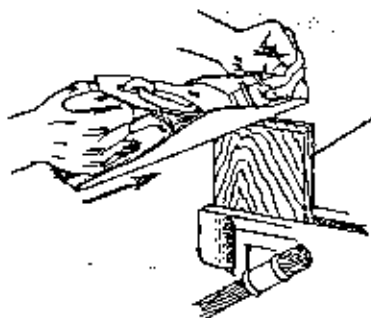


Figure 2-4-11.—Planing a chamfer on the end of a piece of stock.

To get satisfactory results when using an auger bit, make sure the proper bit is selected. Use the bit in the proper manner and make sure the cutting edges are properly fitted and sharp.

SHARPENING AN AUGER BIT

To sharpen an auger bit, select a sharp auger bit file and a suitable place to rest the bit while it is being filed. The edge of the bench, or a piece of wood held in the vise, will be very satisfactory.

A file is sharp when it will "take hold" on a piece of mild steel and produce filings. An auger bit file is about 7 inches long, has spear-shaped ends and a round body. See figure 2-4-14. One end has teeth on the two faces and no teeth on the "safe" edges. The other end has teeth on the edges and no teeth on the "safe"

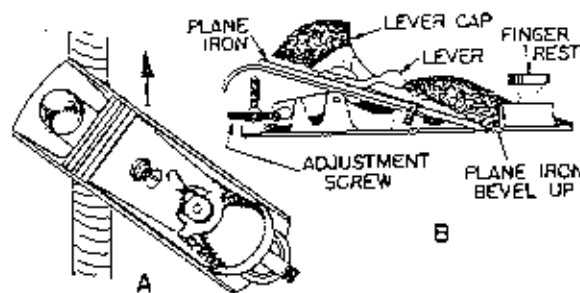
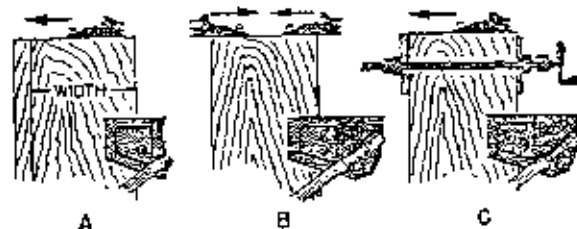


Figure 2-4-12.—Planing across end grain of wood.



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Figure 2-4-13.—Preventing splitting when planing the edge of stock.

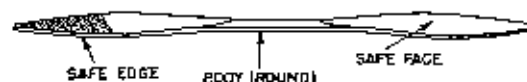


Figure 2-4-14.—An auger bit file.

faces. Safe means having no teeth. Because it is shaped as it is, and has the safe edges and faces, it will not damage the sharpened parts of an auger bit while adjacent parts are being sharpened. These files are made in only one size but will sharpen all sizes of auger bits.

To sharpen the cutting edges of the bit, file only the top surface, following the original bevel established by the manufacturer. See figure 2-4-15. This will retain the proper clearance angle on the underneath face of the twist, as well as the correct cutting-edge angle. Remove the same minimum amount of metal from each of the two edges to keep them equal.

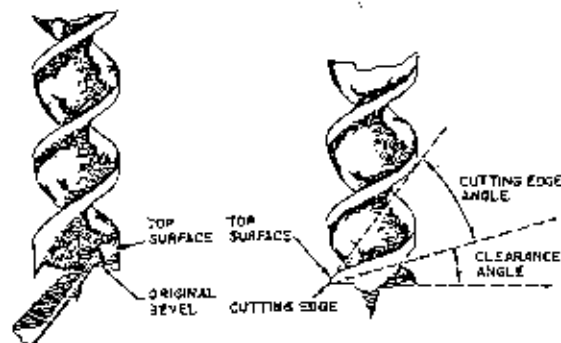


Figure 2-4-15.—Filing an auger bit.

Use the end of the file having the safe edge to protect the adjacent surfaces from damage. To sharpen the spurs, file only on the curved inside edge so as to maintain the full diameter of the bit. See figure 2-4-16.

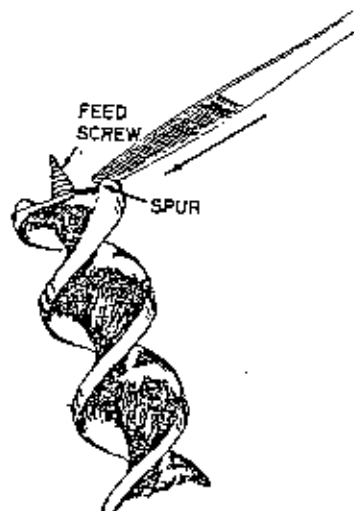


Figure 2-4-16.—Sharpening the spurs of an auger bit.

For exceptionally fine work, whet the cutting edges of the bit with a small, fine stone, preferably an auger bit stone, to improve the file sharpening already done. Figure 2-4-17 shows some types of stones which can be used.

To sharpen or repair damage done to the tapered feed screw of the auger bit, use either an auger bit file or a triangular file. As the feed screw cannot be replaced, and an auger bit usually is worthless without the feed screw, file it as little as possible—just enough to make it usable. Coarse feed screws are, of course, easier to sharpen than those with fine threads.

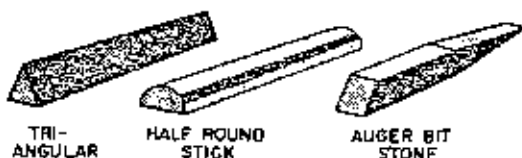


Figure 2-4-17.—Stones used for whetting cutting edges of an auger bit.

In sharpening this screw, follow the original twist and thread pattern, removing the small nicks and sharpening the crest or top of the spiral thread. Rather than risk damaging the feed screw when large nicks are present, just touch up the rough edges of the nicks so they will not tear the fibers of the wood when a hole is bored. A large nick treated in this way will put back into service a bit which otherwise might have to be surveyed. See figure 2-4-18.

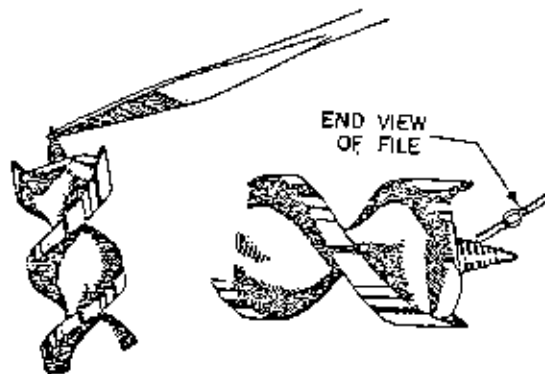


Figure 2-4-18.—Sharpening an auger bit feed screw.

SHARPENING AN EXPANSIVE BIT

To sharpen an expansive bit, sharpen the feed screw just as you would for an auger bit. This will be necessary only if the screw has been damaged by striking nails or being dropped on a hard surface. The three edges of the bit which normally require sharpening are identified in figure 2-4-19 as blade spur, blade-cutting edge, and body-cutting edge. An expansive bit may also have a body spur which would be sharpened as an auger bit spur is sharpened.

To sharpen the cutting edge of the blade, remove the blade from the body and hold it in the vise as shown in figure 2-4-20A. The removable soft jaws will protect the blade from damage. Using an auger bit file, file toward the cutting edge. Maintain angle A by filing the entire surface behind the cutting edge. Note that in figure 2-4-20A the file is in contact with the entire surface.

As filing progresses, a burr will form along the blade-cutting edge on the hollow face of the

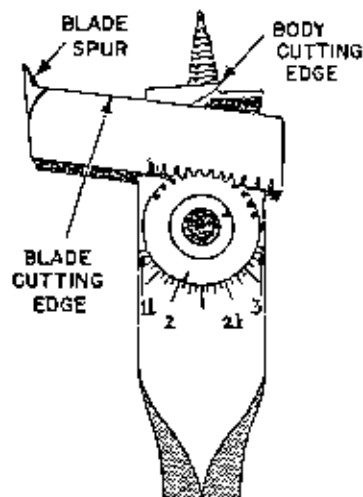


Figure 2-4-19.—Points to be sharpened on an expansive bit.

blade. Remove this with a round edge slip stone, holding the blade in one hand and the stone in the other. See figure 2-4-20.

To sharpen the spur, while the blade is in the vise, proceed as you would to sharpen the spur on an auger bit. This is illustrated in figure 2-4-18.

To sharpen the body-cutting edge, first note its cutting-edge angle and its clearance angle shown in figure 2-4-21A.

Maintain this original shape to provide strength behind the cutting edge. File toward the cutting edge, steadying the bit on the edge of the bench as shown in figure 2-4-21B.

A burr will form on the side opposite the one you have filed. To remove this burr, hold the bit as shown in figure 2-4-21C and file toward the cutting edge, holding the file flat on the surface of the metal behind the cutting edge.

BORING THROUGH HOLES IN WOOD

To bore a through hole in wood with an auger bit, first select the proper fit. Note the figure stamped on or near the square tang. This figure indicates the size, in 16ths of an inch, of the hole that the bit will bore. See figure 2-4-22.

To chuck the bit, hold the shell of the chuck (fig. 2-4-23A) as you turn the handle to open the jaws. When the jaws are apart far enough to take the square tang of the bit, insert it

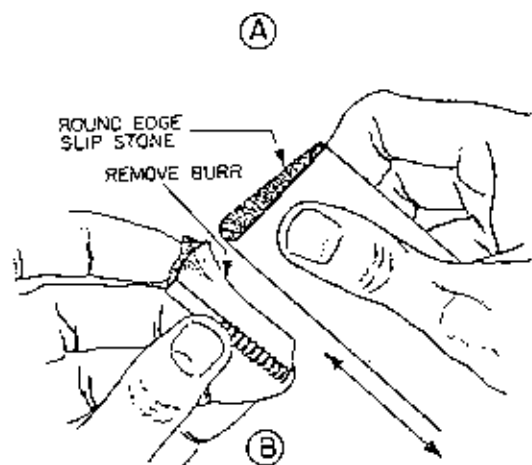
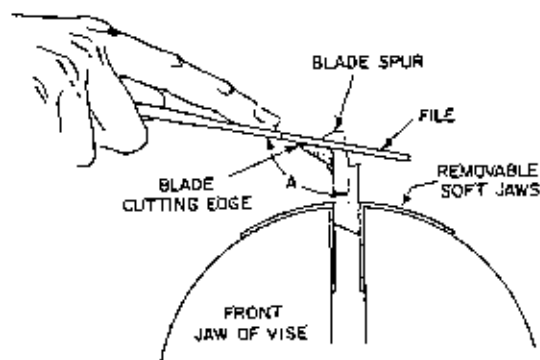


Figure 2-4-20.—Sharpening the cutting blade of an expansive bit.

(fig. 2-4-23B) until the end seats in the square driving socket at the bottom of the chuck. Then tighten the chuck by turning the handle to close the jaws and hold the bit in place.

With a chuck having no driving socket (a square hole which is visible if you look directly into the chuck), additional care must be taken to seat and center the corners of the tapered shank in the V grooves of the chuck jaws. See figure 2-4-23C. In this type of chuck the jaws serve to hold the bit in the center and to prevent it from coming out of the chuck.

After placing the point of the feed screw at the location of the center of the hole you will bore, steady the brace against your body, if possible, with the auger bit square with the surface of the work.

To bore a horizontal hole in stock held in the bench vise, hold the head of the brace with one hand, steadying it against your body, while turning the handle with the other hand. Scrap stock behind the job will prevent splintering. See figure 2-4-24.

When it is not possible to make a full turn with the handle of the bit brace, turn the cam ring, shown in figure 2-4-23A, clockwise until it stops. This will raise one of the two ratchet pawls affording clockwise ratchet action for rotating the bit. For counterclockwise ratchet action, turn the cam ring counterclockwise as far as it will go.

To bore a vertical hole in stock held in a bench vise, hold the brace and bit perpendicular to the surface of the work. Placing a try-square near the bit, alternately in the two positions shown in figure 2-4-25, will help you sight it in.

Another way to bore a through hole without splitting out on the opposite face is to reverse the bit one or two turns when the feed screw just becomes visible through this opposite face (fig. 2-4-26A). This will release the bit. Remove the bit while pulling it up and turning it clockwise. This will remove the loose chips from the hole. Finish the hole by boring from the opposite face. This will remove the remaining material which is usually in the form of a wooden disk held fast to the feed screw. See figure 2-4-26B.

To bore through holes with an expansive bit, you must first clamp a piece of scrap stock behind the job as shown in figure 2-4-27. Then bore through the job and into the scrap stock a few turns, thus leaving a clean cut on the job itself. This method is, of course, also satisfactory when using auger bits. However, boring from both faces, as shown in figure 2-4-26 with an auger bit, does not work well with an expansive bit.

BORING HOLES IN WOOD TO A REQUIRED DEPTH

To bore a hole to a certain depth, especially when several holes of the same depth are needed, use a bit gage. This tool, shown in figure 2-4-28, will fit auger bits up to 1 inch and is clamped

onto the bit as shown. When the two flats on the bottom of the gage come into contact with the surface of the board into which the hole is being bored, the feed screw cannot function. The hole will remain at that particular depth even though the bit is kept turning. The depth setting will be the distance the gage flats are set from the cutting edges of the bit.

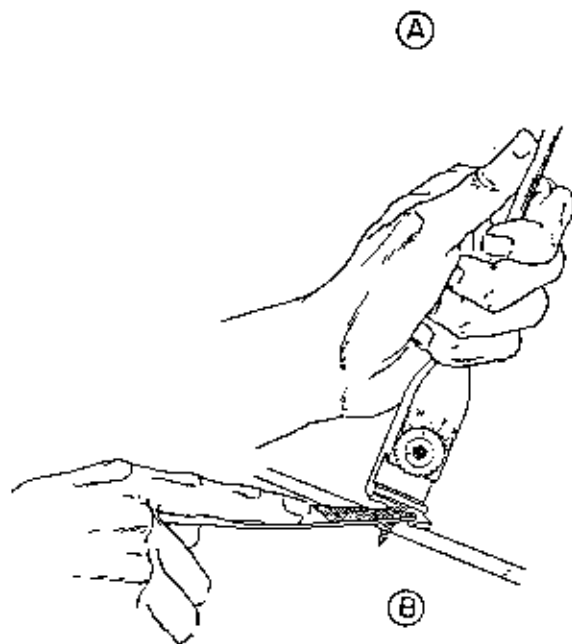
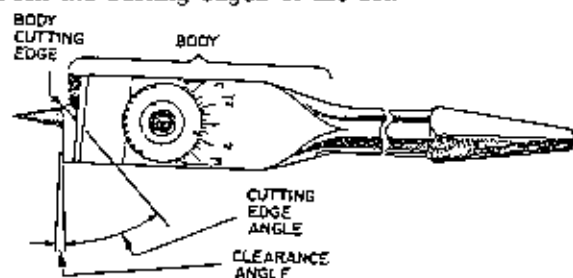


Figure 2-4-21.—Sharpening the body cutting edge of an expansive bit.

A block of wood, with a hole bored lengthwise through it, can be used as a depth gage. Cut the block to whatever length will provide the desired depth setting. See figure 2-4-29 on how to use it.

To bore a hole to a given depth without any type of gage, turn the bit until the cutting edges just start to cut. Then measure the distance, with your rule, from the surface of the wood to the bottom face of the chuck. As you bore the hole, this measurement will decrease. The amount of decrease is the depth of the hole. As an example, if the initial measurement was 5 inches, and after boring for several turns of the auger bit the measurement is 4 inches, the hole will be 1 inch deep. (See figure 2-4-30 (A and B).)

When accuracy is not important, you can measure from the cutting edges of the bit a distance equal to the required depth of the hole and put a mark on the twist of the bit. Bore the hole until this mark, which might be a

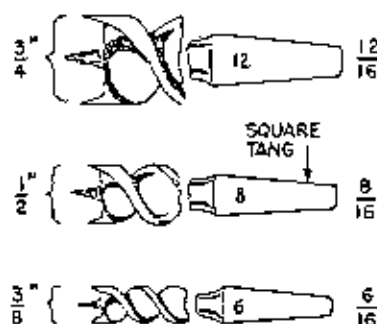
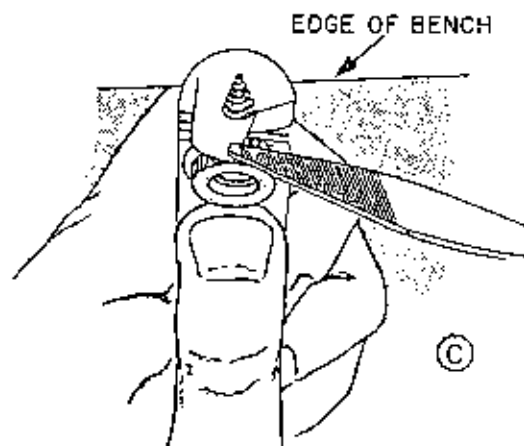


Figure 2-4-22.—Size markings on auger bits.



crayon or pencil mark, reaches the surface of the wood. A piece of friction or scotch tape will serve as a marker, too. (See figure 2-4-30C.) These latter two methods of boring a hole to a certain depth are used when only one hole is to be bored to that depth.

To bore a deep hole, chuck an auger bit in an auger-bit extension and chuck the auger-bit extension in the bit brace.

The effective length of the auger bit will be increased by about the length of the extension, thus enabling you to bore overhead holes, holes which are located so that the bit and brace alone could not reach them, and deep holes. Note that the minimum-size hole that the extension itself will follow into is the diameter of the chuck plus some clearance. (See figure 2-4-31.) This limits its use in boring deep holes to that size or larger, but does not limit its use in boring in hard-to-reach places. If the extension is not to follow into the hole, it may be used with smaller bits. The auger-bit extension is not designed to handle sizes larger

than 1" which take more turning force than it will stand. (See figure 2-4-31.)

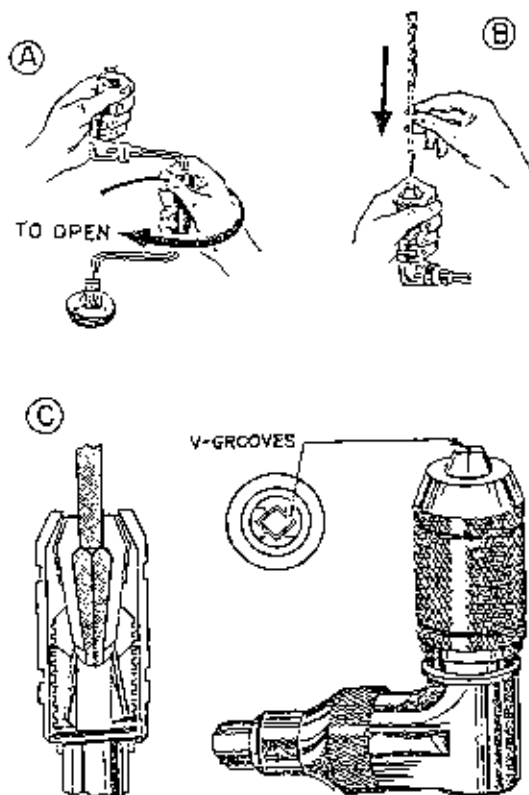


Figure 2-4-23.—Placing an auger bit in a chuck.

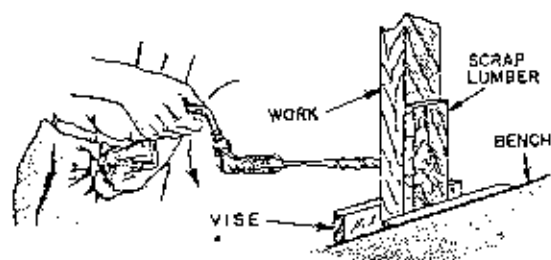


Figure 2-4-24.—Using scrap lumber to prevent splintering when boring.

DRILLING HOLES WITH A TWIST DRILL

An ordinary twist drill may be used to drill holes in wood. Select a twist drill of the size required and secure it in the chuck of a power- or hand-operated drill.

In figure 2-4-32 the twist drill has been chucked in the chuck of a drill press. Notice that the job is secured to the table of the drill press with a pair of C-clamps. Beneath the job is a block of wood. In drilling through wood, a backup block is used to ensure a clean hole at the bottom of the job.

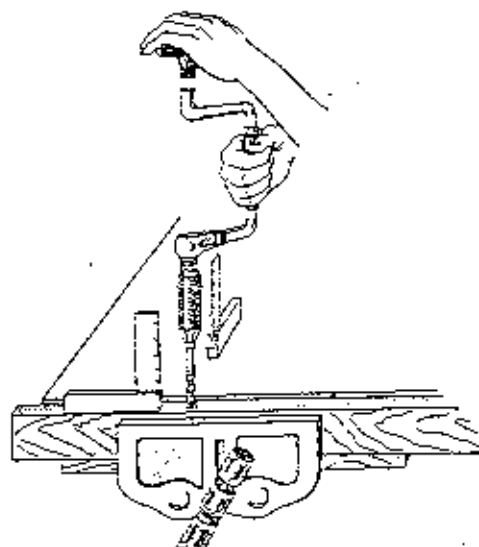


Figure 2-4-25.—Method of sighting in for perpendicular hole.



Figure 2-4-26.—Boring a through hole by reversing direction.

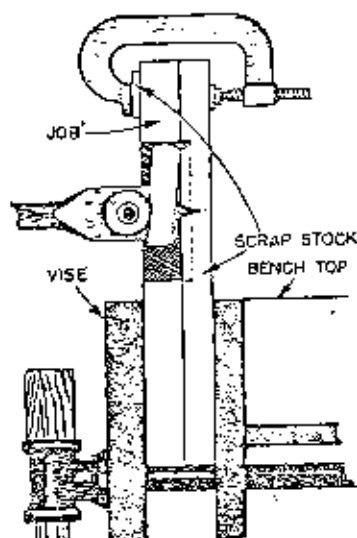


Figure 2-4-27.—Drilling a through hole with an expansion bit.

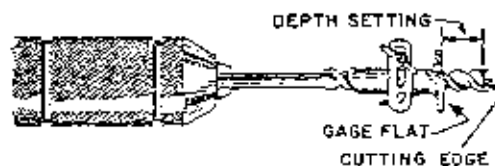


Figure 2-4-28.—Boring a hole using a bit gage.



Figure 2-4-29.—Using a block of wood as a depth gage.

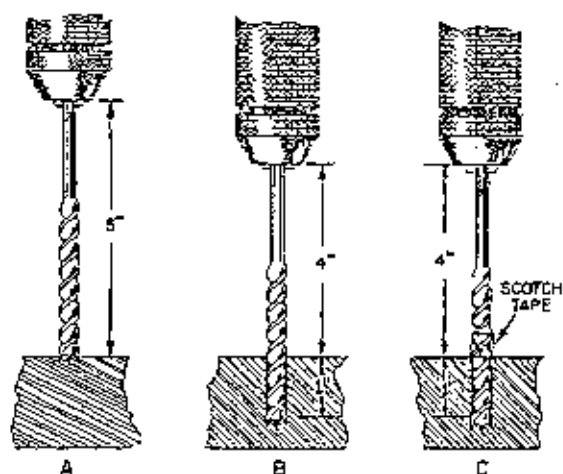


Figure 2-4-30.—Boring a hole to a given depth without a gage.

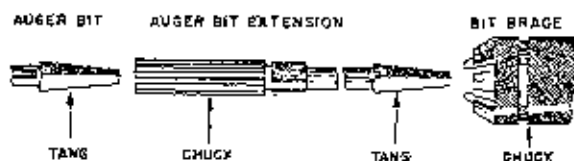


Figure 2-4-31.—Using an auger bit extension.

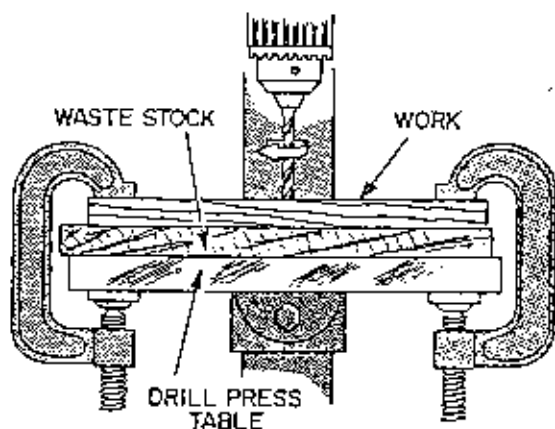


Figure 2-4-32.—Drilling a hole in wood with a twist drill.

An electric hand drill secured in a drill stand will serve in a limited way to take the place of a drill press. However, only the one speed is available and must be used for small and large twist drills alike. When the electric drill is used in a drill stand, rather than offhand, less effort is necessary to feed the

drill into the metal. Also, because the drill is rigidly mounted, less drill breakage is to be expected. In addition, holes will be drilled at right angles to the surface of the work in either the drill stand or the drill press more easily than if the electric drill is held by hand.

Figure 2-4-33 shows a hole being drilled with a breast drill. Turn the crank handle with one hand as you hold the side handle with the other hand. This will steady the breast drill while feed pressure is applied by resting your chest on the breast plate shown in figure 2-4-33. Notice, in figure 2-4-33, that the breast drill has a high or a low speed available, according to the setting of the speed selector nut. When drilling a horizontal hole, apply feed pressure by resting your body against the breast plate.

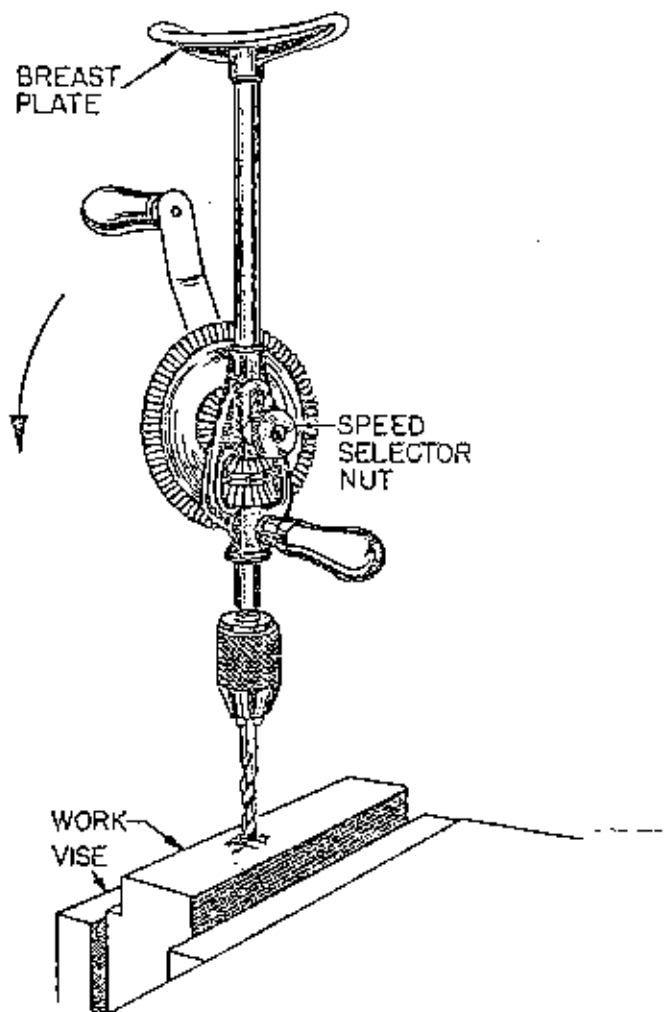


Figure 2-4-33.—Drilling a hole with a breast drill.

In drilling a horizontal hole with the hand drill shown in figure 2-4-34, operate the crank with the right hand and with the left hand guide the drill by holding the handle which is opposite the chuck end of the drill. Get additional feed pressure, if necessary, by carefully leaning against the hand drill with your body.

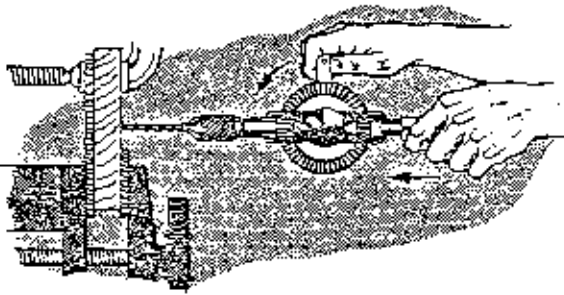


Figure 2-4-34.—Drilling a hole with a hand drill.

DRILLING HOLES WITH A "PUSH" DRILL

Figure 2-4-35A shows the Stanley "Yankee" automatic drill which is often called a "push" drill. This drill can be used to drill either horizontal or vertical holes when the accuracy of the right angle with the work is not critical.

The drill point used in push drills (fig. 2-4-35B) is a straight flute drill. Sharpen its point on the grinder and provide only slight clearance behind the cutting edge. It will drill holes in wood and other soft materials.

To select a drill for use in a push drill, hold the handle of the drill in one hand and release the magazine by turning the knurled screw as shown in figure 2-4-36A. This will permit you to drop the magazine. Figure 2-4-36B shows the drill magazine lowered to expose the drills from which the proper size can be selected.

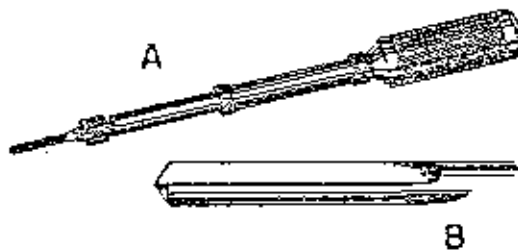


Figure 2-4-35.—Push drill and drill point.

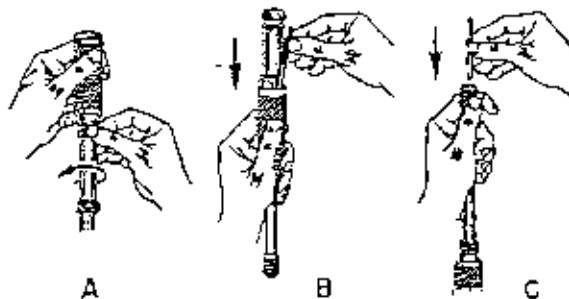


Figure 2-4-36.—Selecting a drill for use in a push drill.

To chuck the drill, loosen the chuck several turns and insert the drill as far as it will go. Turn the drill until it seats in the driving socket in the bottom of the chuck. Then tighten the chuck to hold the drill in place. See figure 2-4-36C.

To drill a vertical hole with this drill (fig. 2-4-37A), place the job on a flat surface and operate the push drill with alternate strokes up and down. If it is necessary to hold the work in place while it is being drilled, use some mechanical means if you can. If you must hold the job with your hand, grasp the material as far as possible from where the drill is drilling.

In drilling horizontal holes with the push drill, as in figure 2-4-37B, secure the job in a vise. The back-and-forth strokes rotate the drill, advancing it into the work on the forward stroke as the drilling proceeds. The index finger, extended along the body of the tool, will help guide the drilling at right angles to the work.

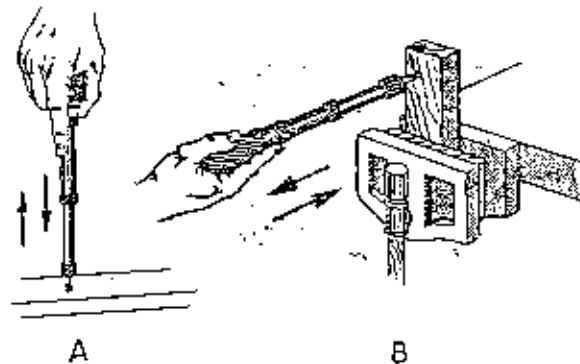


Figure 2-4-37.—Drilling horizontal and vertical holes with a push drill.

DRILLING HOLES FOR WOOD SCREWS

To drill a hole for a wood screw which is used to hold two pieces of hard wood together, as shown in figure 2-4-38, two different sized holes are usually necessary. The wood screw simply passes through the hole in the top piece and the threads take hold in the bottom piece.

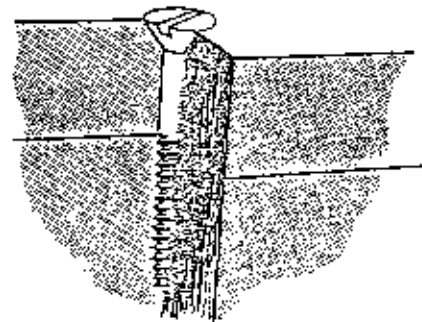


Figure 2-4-38.—Using a screw to hold two pieces of wood together.

In this case, drill the body hole, as shown in figure 2-4-39, completely through the top piece. Notice in figure 2-4-39 that the point of the body drill has just entered the bottom piece.

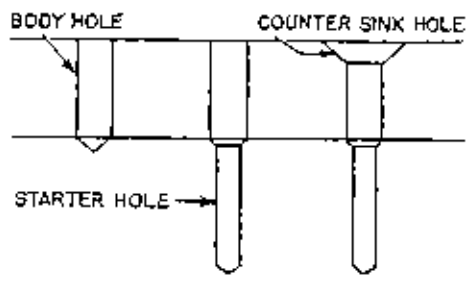


Figure 2-4-39.—Shape of hole for a wood screw.

Then drill the "starter" hole which is the root diameter (or a little less) of the wood screw and therefore somewhat smaller than the body hole. Insert the starter drill through the body hole and continue the drilling with the body hole as a guide. If a flathead wood screw or oval-head wood screw is to be used, countersink the body hole as shown. (Refer to fig. 2-4-43 on how to countersink holes in wood.)

Select the drill sizes according to the dimensions of the wood screw. The names of these dimensions are given in figure 2-4-40.

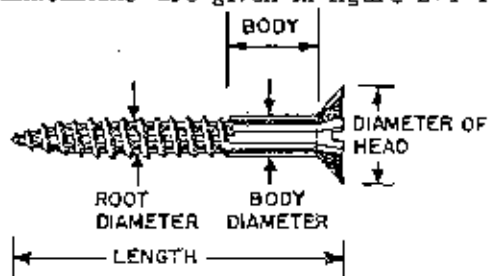


Figure 2-4-40.—Nomenclature of a wood screw.

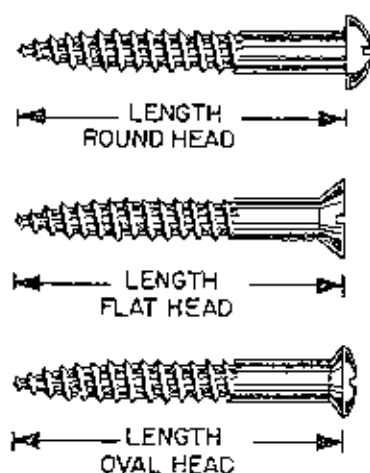


Figure 2-4-41.—Types of wood screws.

Figure 2-4-41 shows the three most common types of wood screws. Notice that the length is always measured from the point to the greatest diameter of the head. As a general rule, the length of the wood screw should be such that the body shown in figure 2-4-40 extends through the piece being screwed down so that the threaded portion will then enter the piece of wood beneath it.

Determine the size of the body hole by holding the body of the screw in front of the graduations on a rule and taking a reading. Then determine the size of the root diameter hole by using the same method and measuring at about the middle of the threaded portion of the screw. Neither of these measurements is critical. Another way to find out what size drills to use for the body hole and the starter hole, when you know the size number of the wood screw you are using, is to refer to the chart shown in figure 2-4-42. To do this, find the proper column according to the size number of the screw, such as No. 14 for instance. Reading down the column you will find that the decimal diameter of its shank is 0.242", or 15/64" stated in a common fraction. You will also find the the body hole should be drilled with a 1/4" twist drill or bored with a No. 4 auger bit, and that the starter hole should be drilled with a 5/32" twist drill. Where no figure is given in the chart for bit size, use the recommended twist drill size. A No. 4 auger bit is the smallest size (1/4") generally available. Because a No. 1 screw is so small, no starter hole is required and therefore no drill or bit sizes are given.

COUNTERSINKING HOLES IN WOOD

To countersink a hole in wood, use a countersink, three types of which are shown in figure 2-4-43. Any one of these will do the job. Turn the countersink at slow speed to ensure a smooth surface on the countersunk portion of the hole.

Countersink deeply enough so that the major diameter of the screwhead is at or just slightly below the surface of the work. Figure 2-4-44 shows one way of determining the proper depth of the countersunk portion of the hole. If many holes are to be countersunk on the drill press, set the depth stop when the proper setting has been determined.

USING WOOD CHISELS

A wood chisel should always be held with the flat side or back of the chisel against the work for smoothing and finishing cuts. Whenever possible, it should not be pushed straight through an opening, but should be moved laterally at the same time that it is pushed forward. This method ensures a shearing cut, which with care, will produce a smooth and even surface even when the work is cross-grained. On rough work, use a hammer or mallet to drive the socket-type chisel.

On fine work, use your hand as the driving power on tang-type chisels. For rough cuts, the bevel edge of the chisel is held against the work. Whenever possible, other tools such as saws and planes should be used to remove as much of the waste as possible, and the chisel used for finishing purposes only.

There are a few basic precautions that you should observe at all times when using a chisel.

DRILL AND AUGER BIT SIZES FOR WOOD SCREWS

SCREW SIZE NUMBER		1	2	3	4	5	6	7	8	9	10	12	14	16	18
NOMINAL SCREW BODY DIAMETER		.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.216	.242	.268	.294
		$\frac{5}{64}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{15}{64}$	$\frac{17}{64}$	$\frac{19}{64}$
BODY HOLE	DRILL SIZE	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{11}{64}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{17}{64}$	$\frac{19}{64}$
	BIT SIZE											4	4	5	5
STARTER HOLE	DRILL SIZE		$\frac{1}{16}$	$\frac{1}{16}$	$\frac{5}{64}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{7}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{9}{64}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{13}{64}$
	BIT SIZE														4

Figure 2-4-42.—Drill and auger bit sizes for wood screw.

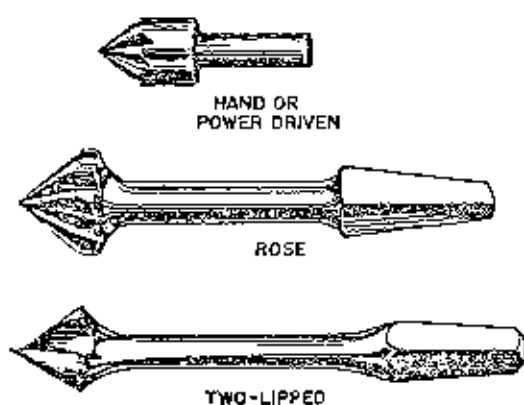


Figure 2-4-43.—Types of wood countersinks.

- Secure work so that it cannot move.
- Keep both hands back of the cutting edge at all times.
- Do not start a cut on a guideline. Start slightly away from it, so that there is a small amount of material to be removed by the finishing cuts.
- When starting a cut, always chisel away from the guideline toward the waste wood, so that no splitting will occur at the edge.
- Never cut towards yourself with a chisel.
- Make the shavings thin, especially when finishing.
- Examine the grain of the wood to see which way it runs. Cut with the grain. This severs the fibers and leaves the wood smooth. Cutting against the grain splits the wood and leaves it rough. This type of cut cannot be controlled.

CHISELING HORIZONTALLY WITH THE GRAIN

To chisel horizontally with the grain, grasp the chisel handle in one hand with the thumb extended towards the blade (fig. 2-4-45). The cut is controlled by holding the blade firmly with the other hand, knuckles up and the hand well back of the cutting edge. The hand on the chisel handle is used to force the chisel

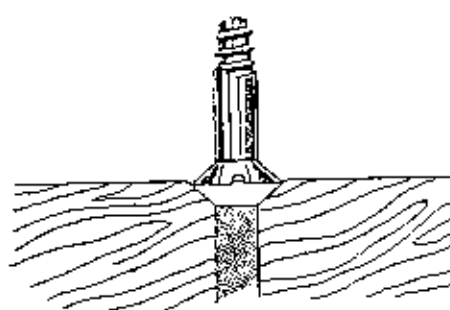


Figure 2-4-44.—Checking countersink portion of hole for size.

into the wood. The other hand pressing downward on the chisel blade regulates the length and depth of the cut.

The chisel will cut more easily and leaves a smoother surface when the cutting edge is held at a slight diagonal to the direction of the

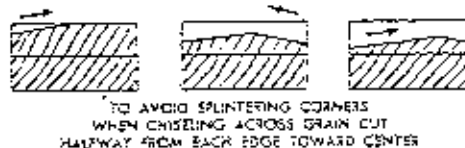
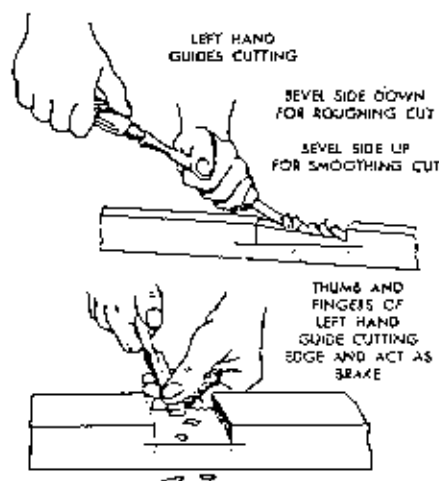


Figure 2-4-45.—Chiseling horizontally across the grain.

cut, or is given a slight lateral sliding motion. This is done by holding the tool at a slight angle and moving it to one side as it is pushed forward, or by moving it slightly from left to right at the same time you push it forward. With cross-grained wood, it is necessary to work from both directions to avoid splitting the wood at the edges. Do not hurry. Cut only fine shavings. If thick shavings are cut, the tool may dig in and split off a piece of wood which was never intended to be removed.

CHISELING HORIZONTALLY ACROSS THE GRAIN

To chisel horizontally across the grain, hold the work so that it does not move. Remove most of the waste wood by using the chisel with the bevel held down. On light work, use hand pressure or light blows on the end of the chisel handle with the palm of the right hand. On heavy work, use a mallet. To avoid splitting at the edges, cut from each edge to the center and slightly upward so that the waste wood at the center is removed last (fig. 2-4-45). Make finishing cuts with the flat side of the chisel down. Never use a mallet when making finishing cuts, even on large work. One-hand pressure is all that is necessary to drive the chisel which is guided by the thumb and forefinger of the other hand. Finish cuts should also be made from each edge toward the center. Do not cut all the way across from one edge to the other or the far edge may split.

CHISELING DIAGONALLY ACROSS THE GRAIN

To chisel diagonally across the grain, such as making a straight slanting corner, remove as much waste wood as possible with a saw. (See fig. 2-4-46.) Hold the work so the guideline is horizontal. Use the chisel as in cutting horizontally with the grain. It is necessary to chisel with the grain and to hold the chisel so that the cutting edge is slightly diagonal to the direction of the cut.

CHAMFERING WITH A CHISEL

A chamfer is made by cutting off and flattening the sharp corner which exists between two surfaces which are at right angles to each other. A plain chamfer runs the full length of the edge and is usually made with a plane. A stopped chamfer does not run the full length of the edge. If a stopped chamfer is long enough, part of it can be planed and the ends finished with a chisel. A short stopped chamfer must be made entirely with a chisel. A chamfer is usually made symmetrically at 45°. Mark guidelines with a pencil; the guidelines for a 45° chamfer will be the same distance back from the edges on both surfaces of the wood (fig. 2-4-47).

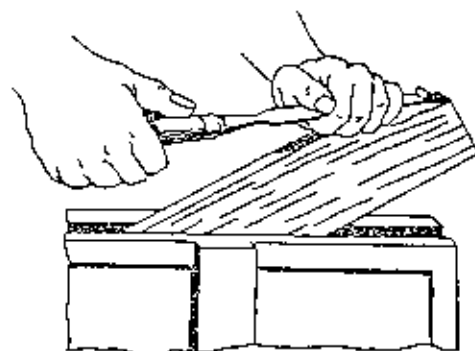


Figure 2-4-46.—Chiseling diagonally across the grain.

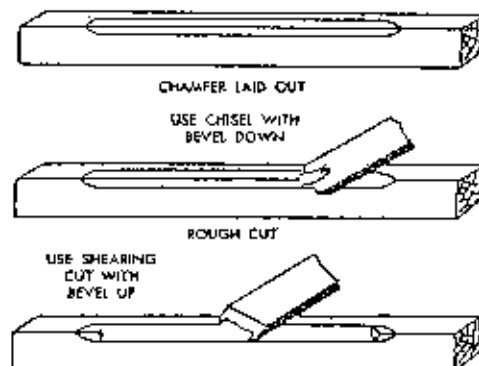


Figure 2-4-47.—Chamfering with a chisel.

NOTE: Do not use a marking gage, scratch awl, or knife to make guidelines, since they leave marks in the wood which are difficult to remove.

To cut a stopped chamfer, hold the chisel with the edge parallel to the slope of the chamfer and cut with the grain as in ordinary horizontal paring. Begin at the ends and work toward the center. The ends of a chamfer may be either flat or curved. If flat, use the chisel with the bevel up. If curved, keep the bevel down when cutting.

CHISELING A ROUND CORNER

To cut a round corner on the end of a piece of wood, first lay out the work and remove as much waste as possible with a saw (fig. 2-4-48). Use the chisel with the bevel side down to make a series of straight cuts tangent to the curve. Move chisel sideways across the work as it is moved forward. Finish curve by paring with the level side up. Convex curves are cut in the same manner as a round corner.

CUTTING A CONCAVE CURVE

When cutting a concave curve with a chisel, remove most of the waste wood with a coping saw or a compass saw. Smooth and finish the curve by chiseling (fig. 2-4-49) with the grain, holding the chisel with the bevel side down. Use one hand to hold the chisel against the work.

Press down on the chisel with the other hand, and, at the same time, draw back on the handle to drive the cutting edge in a sweeping curve. Care must be used to take only light cuts or the work may become damaged.

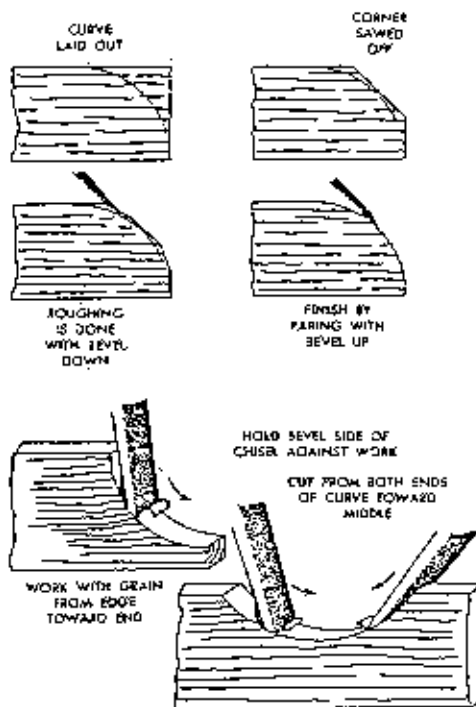


Figure 2-4-48.—Chiseling corners and curves.

VERTICAL CHISELING

Vertical chiseling (fig. 2-4-49) means cutting at right angles to the surface of the wood which is horizontal. Usually it involves cutting across the wood fiber, as in chiseling out the ends of a mortise or making a gain on stopped dado joints. When vertically chiseling across the grain, a mallet may be used to drive the chisel. A mallet is necessary when chiseling hardwood. Use a shearing cut in cutting across the grain.

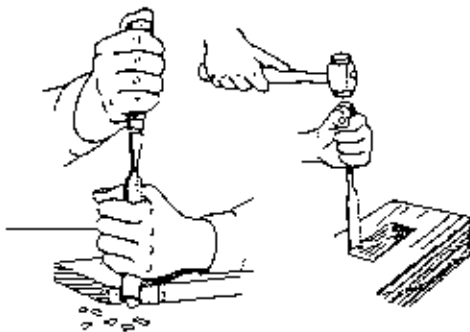


Figure 2-4-49.—Vertical chiseling.

Always cut with the grain whenever possible, so that the waste wood will easily split away from the guidemarks. When chiseling on the ends of wood, remove as much waste wood as

possible with a saw. Observe direction of grain and start to cut at an edge to avoid splitting the wood. Use a shearing cut and make the shavings thin. Thin shavings can be made without the use of a mallet. Grasp the handle of the chisel in one hand with the thumb pressing down on top of the handle, as shown in figure 2-4-49. Use the other hand to guide the tool, and to likewise supply some of the driving force if much pressure is required to do the job.

GRINDING AND FILING OPERATIONS

To keep hand tools in the best usable condition, cutting edges must be sharpened frequently and certain other tools trued or shaped for special purposes. Chisels, punches, drills, tin snips, screwdrivers, and other hand tools are shaped or sharpened on an abrasive grinding wheel.

Grinding may be defined as the act of shaping or wearing down a surface or sharpening an edge by means of the cutting action of thousands of abrasive grains on the surface of the grinding wheel. Excessive grinding shortens the useful life of a tool.

ABRASIVE WHEELS

In any grinding operation, the selection of the proper abrasive wheel is of primary importance. Selection of the right wheel involves such factors as the material of the wheel, the material of the work, the amount of material to be removed from the work, and the nature of the finish required.

COMPOSITION

The abrasives are held together by a bonding agent. The strength with which the bonding agent holds the abrasive grains is known as the grade. Grade might also be described as the relative hardness of the wheel. The grade has considerable effect upon the grinding characteristics of a wheel. Spaces between grains (structure) also affect the result; if these spaces are too small, they may become clogged with metal particles from the work, and the wheel becomes "loaded." A loaded wheel will not grind properly and is likely to mar the work surface.

The standard markings given to grinding wheels by their manufacturers consist of a sequence of symbols. See fig. 2-5-1.

1. Abrasive type. The letter C is used for silicon carbide, and the letter A for aluminum oxide.

2. Grain size. The series 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 220 is commonly used, with the low numbers representing coarse grain and the high ones a very fine grain size. A manufac-

1. Abrasive type _____
2. Grain size _____
3. Grade _____
4. Structure _____
5. Bond type _____
6. Manufacturer's record _____

Figure 2-5-1.—Standard markings given to grinding wheels.

turer may add a number and additional symbol to indicate a special grain combination for special purpose grinding.

3. Grade. This is indicated by a letter of the alphabet, A to Z—soft to hard.

4. Structure. Use of a structure symbol is optional. The general range is from 1 to 15, with the higher numbers indicating less density and wider grain spacing.

5. Bond type. These are indicated as follows: V, vitrified; E, shellac or elastic; S, silicate; R, rubber; B, resinoid; O, oxychloride.

6. Manufacturer's record. The symbol used here has reference to the manufacturer's factory records.

Although the markings given above are standardized, it is nevertheless a fact that wheels with identical markings may have different grinding actions if they are the output of different manufacturers. This is an important point to bear in mind when it becomes necessary to replace a wheel.

Typical wheels required for sharpening cutters and for other types of grinding are illustrated in figure 2-5-2. Reading from left to right the wheels are used as follows: (1) for

cutting off Stellite, high-speed tool steel, tubing, etc.; (2) for grinding end-mills, staggered tooth slotting cutters, reamers; (3) for cylindrical as well as surface grindings; (4) for face mills; (5) the straight cup, for flat forming tools such as lathe and planer cutter bits; (6) for internal grinding; (7) the flaring cup, for face and end mills, helical mills, slotting cutters, reamers; (8) for internal grinding; (9) the dished wheel, for gear cutters, formed cutters, taps.

STORAGE

Proper inspection and proper storage of grinding wheels are important. Wheels should be carefully inspected as soon as they are received, since there is always a possibility of the wheel being damaged in transit. To inspect for cracks, suspend the wheel and then tap it with some light implement, such as the wooden handle of a screwdriver. In doing this, make sure that the wheels are dry and free from sawdust. Vitrified and silicate wheels should emit a clear, metallic ring; wheels of other bonds give a different type of ring.

The detection of any cracks in a wheel is most important. When revolving at high speed, a cracked wheel may fly apart and cause serious injury.

Wheels should always be stored in a dry place. To prevent any shifting of the wheels, use pegs to support them in the storage racks.

DRESSING AN ABRASIVE WHEEL

An abrasive wheel often gets "out-of-round" and the peripheral surface gets out of shape. When this happens it is time to dress or true the wheel.

A dressing tool is provided for dressing an abrasive wheel. The wheel dresser shown in

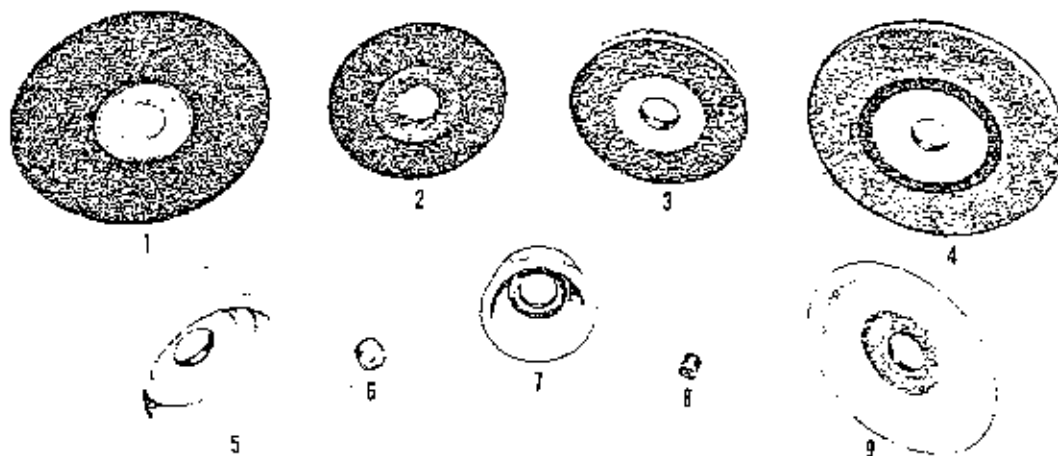


Figure 2-5-2.—Types of grinding wheels.

figure 2-5-3 is the kind usually found in most shops and is very simple to use. Notice that the tool rest has been secured close to the wheel. The "feet" on the bottom of the dresser ride on the tool rest and the cutters touch the wheel.

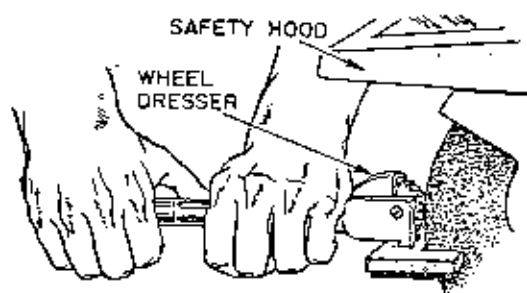


Figure 2-5-3.—Dressing an abrasive wheel with a wheel dresser.

To dress the wheel, start the grinder and, when the wheel is up to speed, move the handle of the dresser ahead to bring the cutters into firm contact with the rotating wheel. Then move the dresser back and forth across the face of the wheel until the surface is clean and approximately square with the sides. This is an eye-hazardous operation. **WEAR YOUR GOGGLES.**

To dress the wheel with an abrasive stick, rest the stick on the tool rest as shown in figure 2-5-4. When the wheel comes up to speed,

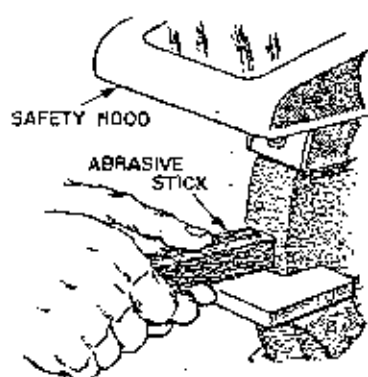


Figure 2-5-4.—Dressing an abrasive wheel with an abrasive stick.

hold the stick against the rotating wheel firmly enough to remove the imbedded particles from the surface of the wheel. Move the stick back and forth across the face of the wheel until the surface is clean and approximately square with the sides. This also is an eye-hazardous operation. **WEAR YOUR GOGGLES.**

GRINDING METAL STOCK

To grind a straight edge on metal stock

(figure 2-5-5,) adjust the tool rest so that it just clears the wheel and is approximately at the center line of the wheel. Then, keeping the edge of the stock parallel with the center line of the grinder shaft, pass the stock across the face of the wheel. Grind across the entire width of the piece, using medium pressure which will keep the wheel cutting but will not appreciably decrease its speed. Grinding across the entire width of the piece and the wheel wears the wheel evenly and helps prevent overheating.

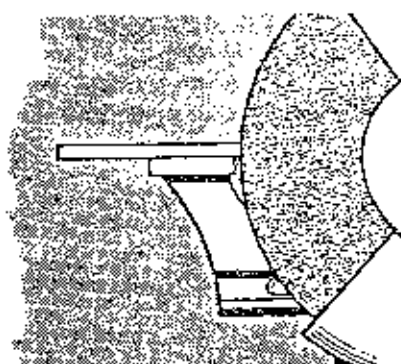


Figure 2-5-5.—Grinding a straight edge on metal stock.

To grind a bevel on an edge, (figure 2-5-6,) hold the stock as shown so that it is resting both on the wheel and on the edge of the tool rest. The edge being ground is away from the tool rest and therefore is not liable to get caught between the tool rest and the wheel. Pass the stock across the face of the wheel from left to right just as you do when grinding a square edge.

To grind a radius, set the tool rest at the center line of the wheel. With one hand, hold the end of the stock being ground so that you can

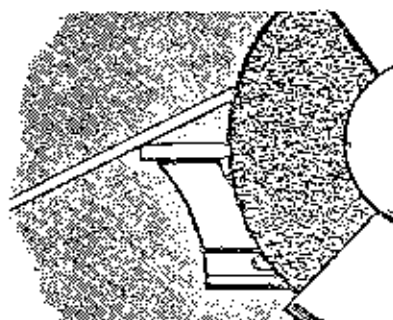


Figure 2-5-6.—Grinding a bevel on metal stock.

move it from left to right, across the face of the wheel, as shown by the small double-headed arrow in figure 2-5-7, and also hold it down firmly on the tool rest. With the other hand swing the arc shown by the longer curved double-headed arrow at the opposite end of the

stock. The motion indicated by the curved arrow will produce the rounded edge on the stock. The travel indicated by the short straight double-headed arrow will prevent the wearing of a groove in the wheel which would have to be removed by dressing.

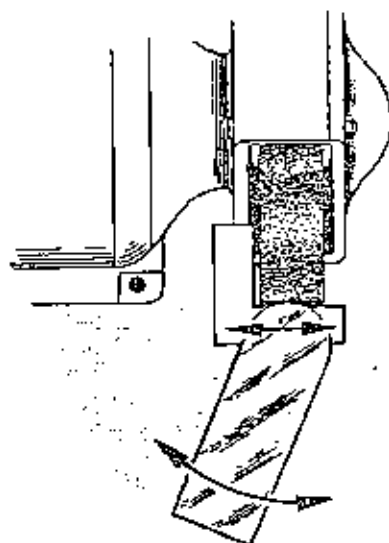


Figure 2-5-7.—Grinding a rounded edge on metal stock.

DRESSING TOOLS

The dressing of tools is an important part of hand tool maintenance. Dressing generally includes grinding the tools when they have become dulled or out of shape, or shaping the tools for specific jobs. There are some power grinders that are designed especially for tool grinding. However, these are not readily available in most small shops. Therefore, most of the tool dressing operations must be done by holding the tool in your hand and grinding it with a bench grinder.

SHARPENING A CENTER PUNCH

To sharpen a center punch, cradle the end of the punch between the index finger and thumb of one hand, as shown in figure 2-5-8, resting that hand on the tool rest of the grinder. Move the punch into light contact with the rotating wheel of the grinder with the center line of the punch forming about a 45° angle with the face of the wheel. This will give the approximate 90° included angle required for a center punch. With the thumb and index finger of the other hand rotate the punch as shown by the directional arrow in figure 2-5-8. Keep the point cool by using only light pressure on the wheel and by frequently dipping the punch in a can of cooling water. Sharpen a prick-punch in the same

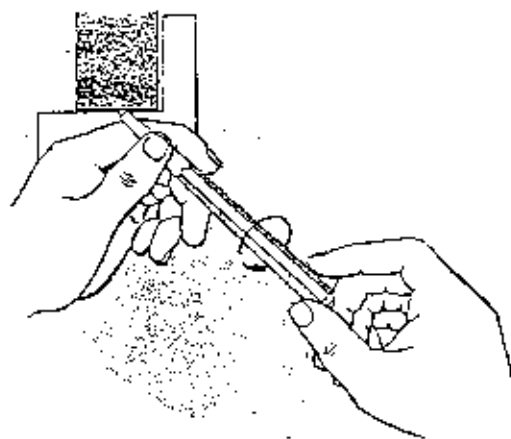


Figure 2-5-8.—Dressing a center punch with a bench grinder.

way with the exception that, since the included angle should be 30° rather than 90° , the angle between the center line of this punch and the wheel should be about 15° .

DRESSING A SCREWDRIVER TIP

To see how to dress the tip of a screwdriver, refer to figure 2-5-9. Figure 2-5-9, parts A and B, are the front and side views of a common screwdriver; 2-5-9 C and 2-5-9 D are the front and side views of what is usually called an electrician's screwdriver.

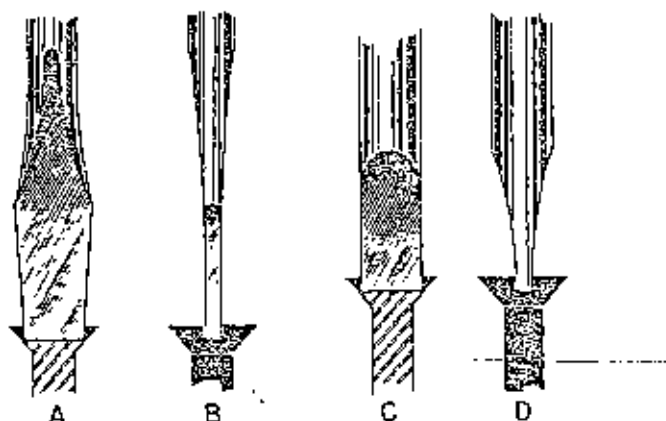


Figure 2-5-9.—Shapes of screwdrivers when properly dressed.

To dress a common screwdriver, dress the sides so that the blade is symmetrical in shape. With electricians' screwdrivers, which are not forged at the tip, and therefore do not have the wide blade that the common screwdriver has, the width of the tip is determined by the diameter of the stock from which the shank is made.

Then, on both types, square off the end. Check the squareness of the end by resting the tip on the handle of a try-square and moving the shank of the screwdriver close to the blade of

the square. If the blade and the shank appear to be parallel, the tip is square. See figure 2-5-10.

On the common screwdriver, grind the faces of the blade so that they are parallel or nearly parallel at the tip as shown at B and D in figure 2-5-9. The thickness of the blade at the tip should be such that the tip will just enter the slot of the screws you intend to turn. With such

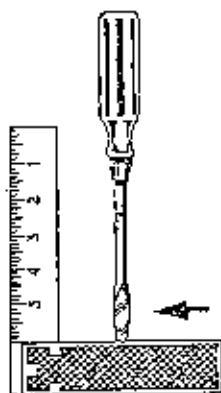


Figure 2-5-10.—Checking the squareness of the end of a screwdriver.

a tip thickness, and the sides parallel or nearly so, the screwdriver will have the least tendency to climb out of the screw slot when the screw is being turned home.

The electrician's screwdriver (or cabinet screwdriver) shown in 2-5-9 D has been ground by resting it flat against the grinding wheel. A 6-inch wheel produces about the right grind on a screwdriver used for small screws. Hold the blade high on the circumference of the wheel and rest the shank on the tool rest. See figure 2-5-11.

When grinding a screwdriver, do not let the tip get too hot or the temper will be drawn—overheating is discussed later in the section on sharpening metal cutting chisels.

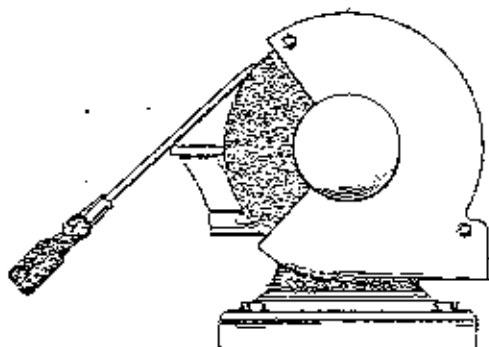


Figure 2-5-11.—Grinding a screwdriver tip with a bench grinder.

SHARPENING TIN SNIPS

To sharpen tin snips on a grinder, open the snips as shown in figure 2-5-12, resting the blade on the tool rest. Hold the handle of the blade being ground level and the handle of the other blade level or slanting downward at whatever angle is necessary to grind the cutting edge to an included angle of 80° to 85°. Holding the blade lightly against the rotating wheel, move it from left to right across the face of the wheel. Sharpen first one blade of the snips and then the other. While sharpening one blade, be careful to keep the other blade from coming into contact with the side of the wheel. Sharpening tin snips requires close and careful attention; improper techniques may result in wrecking the snips or even in serious injury.

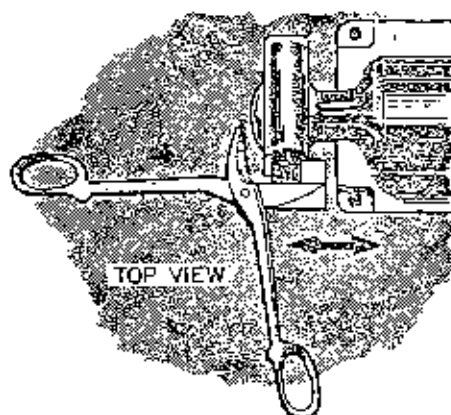


Figure 2-5-12.—Sharpening snips on a grinder.

GRINDING THE HEADS OF CHISELS

The mushroom head on the chisel shown in figure 2-5-13B is very dangerous. When struck with a hammer, chips may break off and injure you or others.

Remove the ragged edges of such a head by grinding them off. One way to do this is to hold the head against the wheel as shown in figure 2-5-14.

Turn the chisel with one hand as you apply pressure with the other. Grind across the entire face of the wheel to keep it flat. In figure 2-5-13 A you will see a properly ground head. Keep it that way by frequent grinding before it begins to mushroom as shown in figure 2-5-13 B.

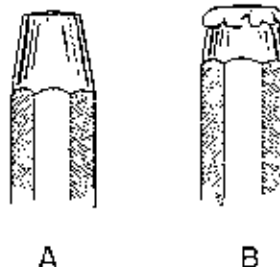


Figure 2-5-13.—Good and bad shaped chisel heads.

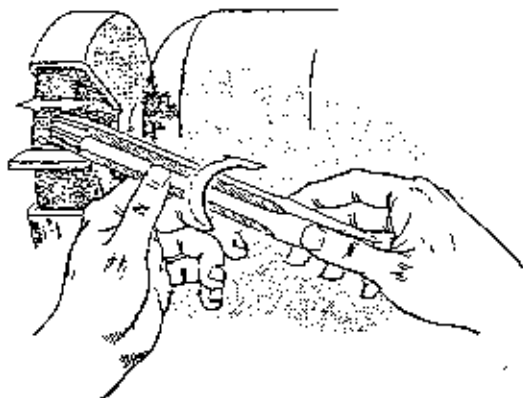


Figure 2-5-14.—Grinding a chisel head with a bench grinder.

SHARPENING METAL CUTTING CHISELS

Metal cutting chisels, types of which are shown in figure 2-5-15, are sharpened by grinding. These chisels are designed to cut cold metal, and the cold chisel is the most common type. The general term "cold chisel" is often used when referring to any one of the chisels shown. The angle of 60° , shown on the cold chisel in figure 2-5-16, is for a general-use cold chisel. Increase this angle somewhat for cutting harder metals and decrease it for those that are softer.

To sharpen a metal-cutting chisel, hold the chisel to the wheel, resting it on the tool rest. (See figure 2-5-17.) Notice that the index finger, curved beneath the chisel, rides against the front edge of the tool rest. This affords good control of the chisel and will help you to grind a single, equal bevel on each side.

Figure 2-5-18 A shows a cold chisel ground with a slight radius, and figure 2-5-18 B shows a straight cutting edge. Both types of edges are used. The radius (fig. 2-5-18 A) is ground by swinging either end of the chisel slightly from left to right as the two faces of the cutting edge are being ground.

For shearing metal in a vise the chisel with the straight edge may be better. The chisel with the slight radius will probably work better when you are cutting metal on a flat plate.

Notice, in figure 2-5-17, that a container of cooling water is near the tool rest. Let the chisel rest only lightly against the wheel when grinding. Less heat will be developed and, because the speed of the wheel is reduced only slightly, the air currents created by the wheel will have the maximum cooling effect. If the temperature of the cutting edge rises to the point where the metal begins to turn blue in color, the temper has been drawn, the cutting edge has been softened, and the edge will not stand up in use. The cutting edge will have to be rehardened, drawn to the proper temper (hardness), and the sharpening continued. As long as you can touch the cutting edge you are

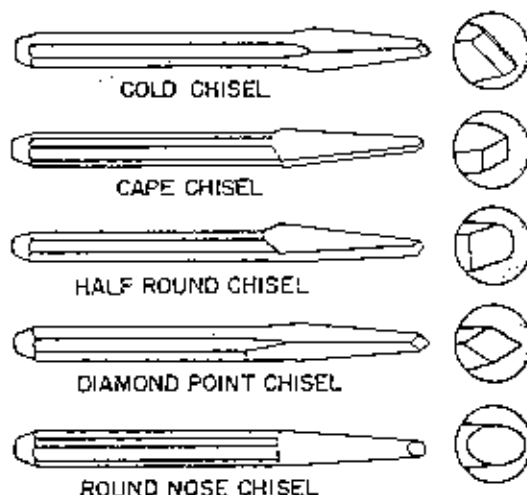


Figure 2-5-15.—Types of points on metal cutting chisels.

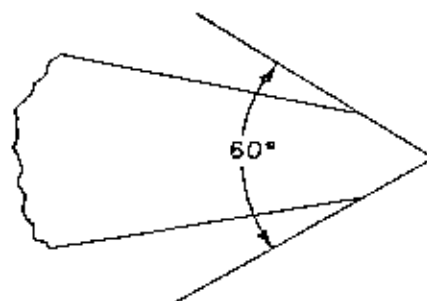


Figure 2-5-16.—Proper angle for general use cold chisel.

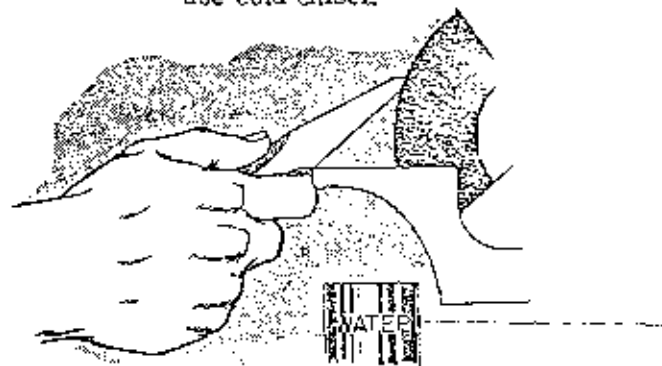


Figure 2-5-17.—Sharpening a chisel with a grinder.

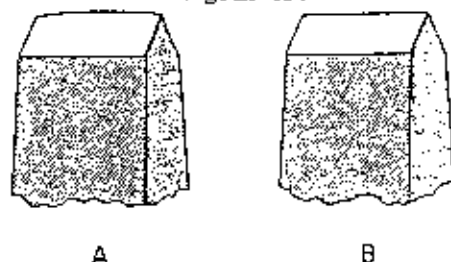


Figure 2-5-18.—Two common shapes of the cutting edges of cold chisels.

grinding with your bare hand and keep it there, you are in no danger of drawing the temper. Notice that it is the temperature of the cutting edge that is important. This means the very tip of the chisel where the bevel is being ground. The chisel at a point an inch or less from the cutting edge may be cool, while the cutting edge itself turns blue from overheating. Check this carefully while grinding.

SHARPENING TWIST DRILLS

The following requirements are of greatest importance in twist-drill grinding: (1) equal and correctly sized drill-point angles, (2) equal-length cutting lips, (3) correct clearance behind the cutting lips, and (4) correct chisel-edge angle. All four are equally important when grinding either a regular point (fig. 2-5-19) which is used for general purposes, or a flat point (fig. 2-5-20) which is used for drilling hard and tough materials.

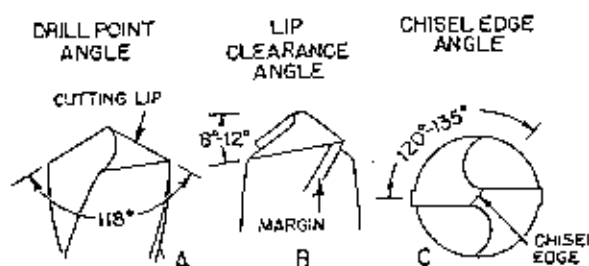


Figure 2-5-19.—Specifications for grinding a regular point twist drill.

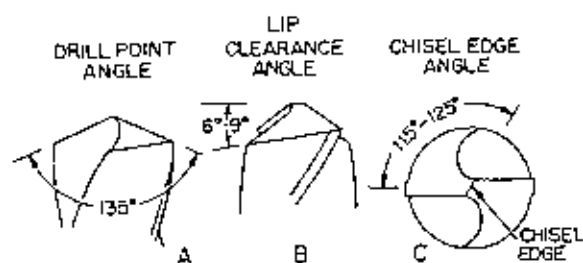


Figure 2-5-20.—Specifications for grinding a flat point twist drill.

Figure 2-5-21 shows what is meant by the two halves, A1 and A2, of the drill point angle, as well as the two equal-length cutting lips, L1 and L2.

Figure 2-5-22 shows a drill being checked during grinding. The drill-point gage is being held against the body of the drill and has been brought down to where the graduated edge of the gage is in contact with one cutting edge. In this

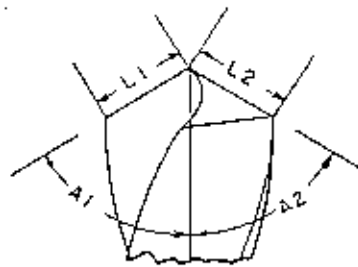


Figure 2-5-21.—Halves and cutting lips of a twist drill.

way, both the drill-point angle and the length of the cutting edge (or lip) are checked at the same time. The process is repeated for the other side of the drill.

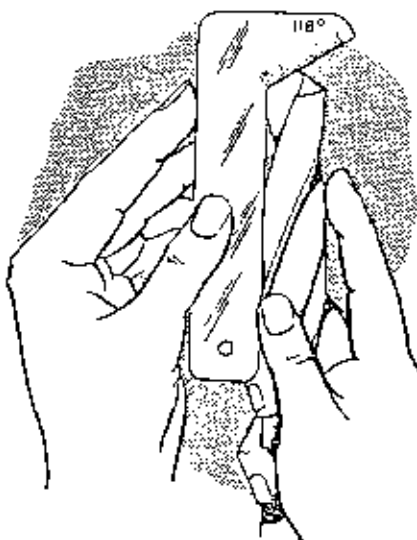


Figure 2-5-22.—Checking the drill point angle and cutting edge.

Lip clearance behind the cutting lip at the margin is determined by inspection. This means that you look at the drill point and approximate the lip-clearance angle (see figs. 2-5-19B and 2-5-20B), or compare it to the same angle that has been set up on a protractor. The lip-clearance angle is not necessarily a definite angle, but must be within certain limits. Notice that in figure 2-5-19 B it ranges from 8° to 12° and that the range given in figure 2-5-20 B is 6° to 9°, which overlaps the first range somewhat. Whatever angle in the range is used, however, lip clearance should be the same for both cutting lips of the drill.

There must be lip clearance behind the entire length of the cutting lip which extends from the margin of the drill to the chisel edge. This means that there must be "relief" behind the cutting lip along its entire length.

Whereas the lip clearance at the margin is measured by inspection, as shown in figures 2-5-19B and 2-5-20B, lip clearance at the other end

of the cutting lip (at the chisel edge) is measured by inspection of the chisel-edge angle. The clearance behind the cutting lip at the chisel edge is greater than at the margin. The chisel-edge angle indicates how much clearance there is behind the cutting lip where it meets the chisel edge. As you grind more clearance behind the cutting lip near the chisel edge, the chisel-edge angle will get larger.

For a regular point, the chisel-edge angle can vary from 120° to 135° and the lip-clearance angle can vary from 8° to 12° . See figure 2-5-19 again.

For a flat point, the chisel-edge angle can vary from 115° to 125° and the lip-clearance angle from 6° to 9° . See figure 2-5-20 again. The greater these angles are in both cases, the more lip clearance there will be, and vice versa.

When lip clearance is being "ground into" a drill, inspection of the lip-clearance angle (shown at B in figs. 2-5-19 and 2-5-20) and of the chisel-point angle (shown at C in figs. 2-5-19 and 2-5-20) will be your guide to the amount of clearance you have ground into the drill behind the cutting lip along its entire length. The greater these angles are, the more clearance there will be behind their respective ends of the cutting lip. Too much lip clearance, which occurs when both the lip-clearance angle and the chisel-edge angle exceed their top limits, weakens the cutting edge or lip by removing too much metal directly behind it. Too little or no lip clearance, prevents the cutting edge from producing a chip, or cutting, and the drill will not drill a hole.

To SHARPEN TWIST DRILLS, first get the grinder ready. If necessary, dress the face of the wheel so that it is clean, a true circle, and square with the sides. Before starting the grinder, readjust the tool rest to $1/16''$ or less from the face of the wheel. This is an important safety measure which will help keep work from wedging between the tool rest and the face of the wheel.

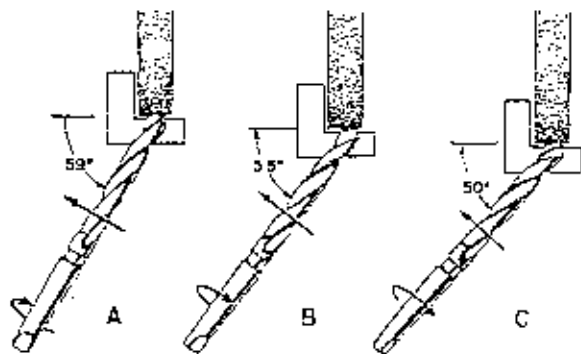


Figure 2-5-23.—Grinding a twist drill with a grinder.

Now, start the grinder and when it has come up to speed, hold the twist drill as shown in

figure 2-5-23A, which is a top view of the first step in grinding a drill. The axis of the drill, in the first step, should make an angle of about 59° (half of the drill-point angle in fig. 2-5-23A) with the face of the wheel. The cutting lip should be horizontal.

Figure 2-5-24 is an actual photograph, side view, of the same drill position which is shown in figure 2-5-23A.

The actual grinding of the drill point consists of three definite motions of the shank of the drill while the point is held lightly against the rotating wheel. These three motions are: (1) to the left, (2) clockwise rotation, (3) downward.

Figure 2-5-23 shows the motion to the left in three views as the angle between the face of the wheel and the drill decreases from about 59° to about 50° .

In figure 2-5-23 the clockwise rotation is indicated by the advance of the rotation arrows in A, B, and C. Rotation is also pictured by the change in position of the cutting lip as well as that of the tang.

Because figure 2-5-23 is a top view, the third (downward) motion is not noticeable. However, all three motions are apparent when an actual photograph of the final position of the

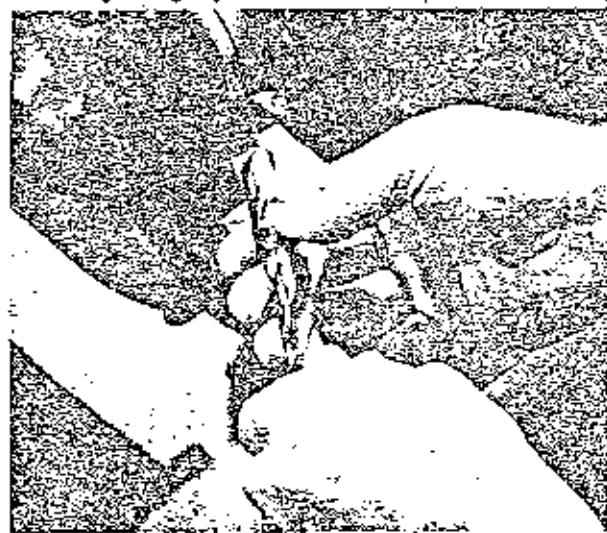


Figure 2-5-24.—Grinding a twist drill with a grinder.

drill in figure 2-5-25 is compared to the initial position in figure 2-5-24. All three motions taking place at the same time combine to produce the important requirements mentioned before (1) equal and correctly sized drill-point angles (2) equal-length cutting lips, (3) correct clearance behind the cutting lips, and (4) correct chisel-edge angle. Checking by means of a drill-point gage, figure 2-5-22, and by inspection will show when these four requirements have been met.



Figure 2-5-25.—Grinding a twist drill with a grinder.

SHARPENING A TWIST DRILL FOR DRILLING BRASS

To grind a drill for drilling brass (fig. 2-5-26 A) hold the cutting lip against the right side of the wheel as shown in figure 2-5-26 B. Grinding the flute slightly flat, in line with the axis of the drill, greatly reduces the included angle of the cutting lip. This will give the drill a scraping action, necessary for brass, rather than the cutting action used for steel. This scraping action will prevent the tendency, that invariably occurs with drills not ground for brass, to stick in the hole being drilled. This sticking is troublesome especially when drilling through a pilot hole.

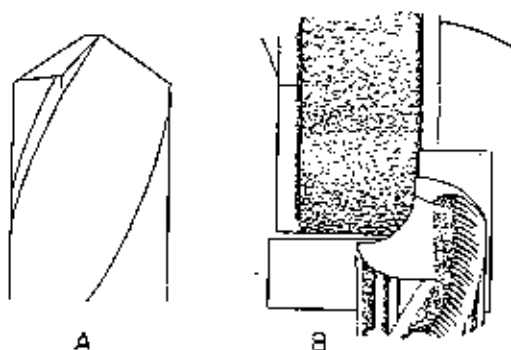


Figure 2-5-26.—Grinding a twist drill for brass.

THINNING THE WEB OF A TWIST DRILL

Repeated sharpening, which shortens the drill, or the fact that the remaining length of a broken drill has been resharpened, results in an increase in the web thickness at the point. This may require web thinning. Correct web thinning, when it becomes necessary, is important for satisfactory drilling.

To thin the web of a drill, hold the drill lightly to the face of a round-faced wheel, as shown in figure 2-5-27A, thinning the web for a short distance behind the cutting lip and into the flutes. This is shown in figure 2-5-27B. Notice that the cutting lip is actually (but only slightly) ground back, reducing its included angle only a very little and not enough to affect the operation of the drill.

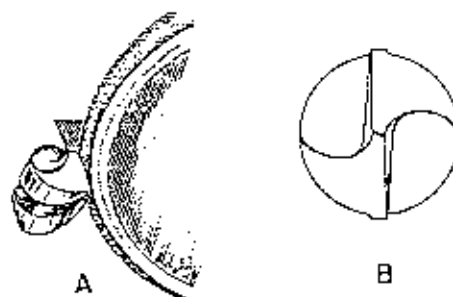


Figure 2-5-27.—Thinning the web of a twist drill.

SHARPENING TWIST DRILL BY MACHINE

Sharpening a twist drill by hand is a skill that is mastered only after much practice and careful attention to the details. Therefore, whenever possible, use a tool grinder in which the drills can be properly positioned, clamped in place and set with precision for the various angles. This machine grinding (fig. 2-5-28) will enable you to sharpen the drills accurately. As a result, they will last longer and will produce more accurate holes.

Whether you are sharpening a drill by hand or by machine, it is very necessary that the temperature at the point be kept down. As the point gets hot, it approaches the temperature at which the temper of the steel will be drawn. To draw the temper means to remove the hardness.

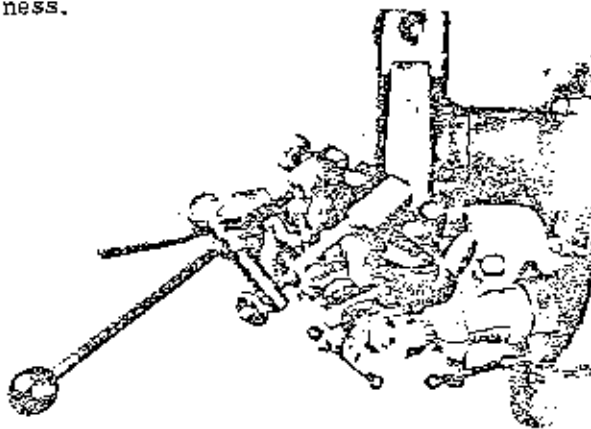


Figure 2-5-28.—Sharpening a twist drill with a tool grinder.

Keep the point cool enough to be held in your bare hand. Do this by making a few light passes over the grinding wheel, take a few seconds to let the point cool and repeat alternate grinding and cooling. With only slight pressure against the wheel, less heat is developed and the speed of the wheel is maintained. Wheel speed creates air currents which also help to keep the point cool.

Once you notice the appearance of a blue temper color at the point, it is too late. You have drawn the temper and the steel is now too soft to hold a cutting edge. Then the only thing you can do is to continue the sharpening process, first one lip and then the other, until you have finally ground away the soft tip of the drill. This means that you must grind away all that portion of the tip which is blue. As the blue color indicates softness throughout the entire point of the drill, and not only on the blue surface, resharpening must be continued until all of the blue-colored metal has been ground away.

This operation must be done very slowly and carefully, keeping the point cool to prevent continual bluing of the metal.

FILING OPERATIONS

Using a file is an operation that is nearly indispensable when working with metal. Filing is done when a small amount of metal is to be removed.

When you have finished using a file it may be necessary to use an abrasive cloth or paper to finish the product. Whether this is necessary depends on how fine a finish you want on the work.

FILING MILD STEEL

Figure 2-5-29 shows a piece of mild steel being crossfiled. This means that the file is being moved across the surface of the work in approximately a crosswise direction. For good results, keep your feet spread apart to steady yourself as you file with slow full-length steady strokes. The file cuts as you push it—ease up on the return stroke to keep from dulling the teeth. Keep your file clean.

Figure 2-5-30 shows the alternate positions of the file when an exceptionally flat surface is required. Using either one position or the

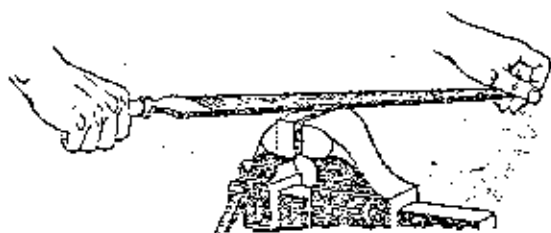


Figure 2-5-29.—Crossfiling a piece of mild steel.

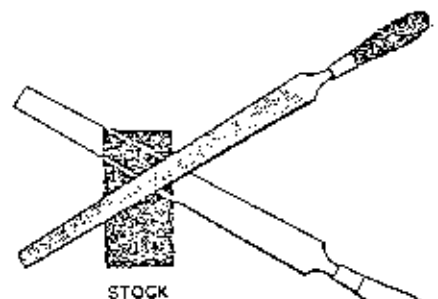


Figure 2-5-30.—Alternating positions when filing.

other first, file across the entire length of the stock. Repeat this until the entire surface has had metal removed by the file. Then, using the other position, file across the entire length of the stock again. Because the teeth of the file pass over the surface of the stock from two directions, the high spots and low spots will readily be visible after filing in both positions. Continue filing first in one position or direction and then the other until the surface has been filed flat. Test the flatness with a straight edge or with prussian blue and a surface plate.

Draw filing produces a finer surface finish and usually a flatter surface than crossfiling. Small parts, as shown in figure 2-5-31, are best held in a vise. Hold the file as shown in the figure; notice that the arrow indicates that the cutting stroke is away from you when the handle of the file is held in the right hand. If the handle is held in the left hand, the cutting stroke will be toward you.

Lift the file away from the surface of the work on the return stroke. When draw filing will no longer improve the surface texture, wrap a piece of abrasive cloth around the file and polish the surface as shown in figure 2-5-32.

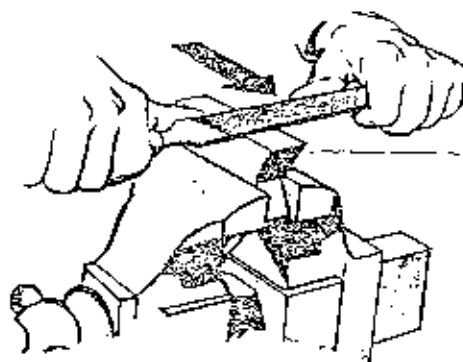


Figure 2-5-31.—Drawfiling a small part.

Always keep the file clean, whether you're filing mild steel or other metals. Use chalk liberally when filing nonferrous metals.

POLISHING A FLAT METAL SURFACE

When polishing a flat metal surface, first

draw file the surface as shown in fig. 2-5-31.

Then, when the best possible draw filed surface has been obtained, proceed with abrasive cloth, often called emery cloth. Select a grade of cloth suited to the draw filing. If the draw filing was well done only a fine cloth will be needed to do the polishing.

If your cloth is in a roll, and the job you are polishing is the size that would be held in a vise, tear off a 6" or 8" length of the 1" or 2" width. If you are using sheets of abrasive cloth, tear off a strip from the long edge of the 8" by 11" sheet.

Wrap the cloth around the file (fig. 2-5-32) and hold the file as you would for draw filing.

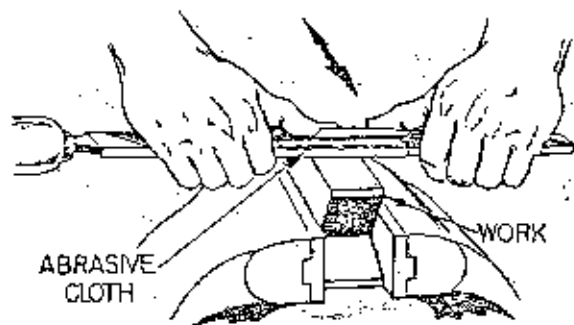


Figure 2-5-32.—Polishing metal with abrasive cloth wrapped around a file.

Hold the end of the cloth in place with your thumb. In polishing, use a double stroke with pressure on both the forward and the backward strokes. Note that this is different from the drawfiling stroke in which you cut with the file in only one direction. Use lubricating oil on the surface being polished.

When further polishing does not appear to improve the surface, you are ready to use the next finer grade of cloth. Before changing to the finer grade, however, reverse the cloth so that its back is toward the surface being polished.

Work the reversed cloth back and forth in the abrasive-laden oil as an intermediate step between grades of abrasive cloth. Then, with the solvent available in your shop, clean the job thoroughly before proceeding with the next finer grade of cloth. Careful cleaning between grades helps to ensure freedom from scratches.

For the final polish, use a strip of crocus cloth—first the face and then the back—with plenty of oil. When polishing is complete, again carefully clean the job with a solvent and protect it, with oil or other means, from rusting.

Figure 2-5-33A shows another way to polish in which the abrasive cloth is wrapped around a block of wood. In figure 2-5-33B, the cloth has simply been folded to form a pad from which a worn, dull surface can be removed by simply tearing it off to expose a new surface.

FILED ROUND METAL STOCK

Figure 2-5-34 shows that, as a file is passed over the surface of round work, its angle with the

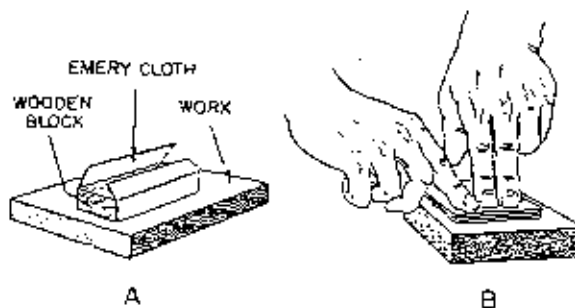


Figure 2-5-33.—Alternate methods for polishing metal surfaces.

work is changed. This results in a rocking motion of the file as it passes over the work. This rocking motion permits all the teeth on the file to make contact and cut as they pass over the work's surface, thus tending to keep the file much cleaner and thereby doing better work.

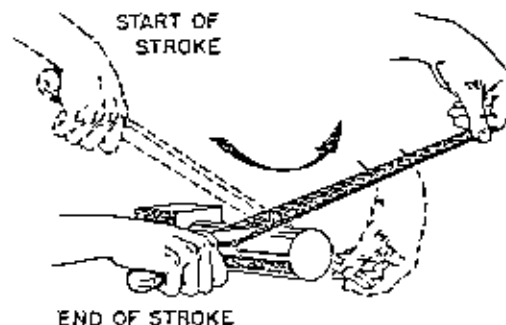


Figure 2-5-34.—Filing round metal stock.

POLISHING ROUND METAL STOCK

In figure 2-5-35, a piece of round stock is being polished with a strip of abrasive cloth which is "seesawed" back and forth as it is guided over the surface being polished.

Remember that the selection of grades of abrasive cloth, the application of oil, and the cleaning between grades, applies to polishing regardless of how the cloth is held or used.

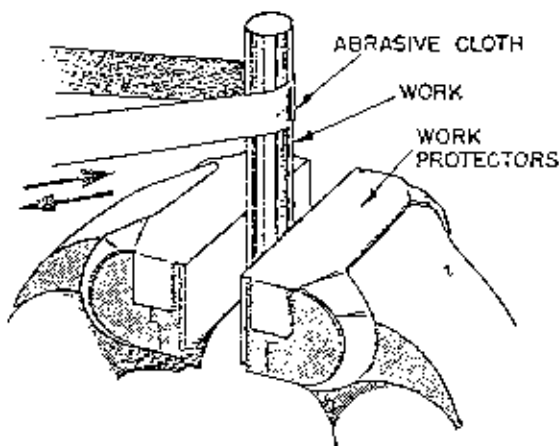


Figure 2-5-35.—Polishing round metal stock.

TESTING METAL FOR HARDNESS

A quick and practical test for hardness can be made with an ordinary mill file. Hold a piece of stock in a vise, or firmly against the edge of the bench, and pass the file over its surface, preferably at an edge or at a corner. If the file will take hold and cut the surface of the metal, it indicates that the metal is softer than the file itself and can therefore be filed, drilled or cut with a hacksaw. If the file seems to slide over the surface of the metal, then its teeth are not cutting, and the metal cannot be drilled with twist drills or cut with a hacksaw. In this case, other methods of cutting will have to be employed. Among these methods are grinding, abrasive wheel cutting, and torch cutting.

USING SHARPENING STONES

Sharpening stones are often used for final dressing of edged tools. When a tool is ground with a grinder there is often a wire edge that should be removed. This can be done by honing the edge of the tool with a sharpening stone. There are many times when the sharp edge of a tool is dulled but is not damaged to the extent that it needs grinding. In these cases honing with a sharpening stone is all that is necessary to restore the keen edge to the tool. Do not grind a tool unless it is necessary, as it will wear away metal unnecessarily and may distort the original shape of the tool.

SHARPENING A CHISEL ON A SHARPENING STONE

To sharpen a wood chisel with a sharpening stone, use a common oilstone that has coarse grit on one side and fine grit on the other. (See fig. 2-5-36.) Make sure the stone is firmly held so that it cannot move. Cover the stone with a light machine oil so that the fine particles of steel ground off will float and thus prevent the stone from clogging.

Hold the chisel in one hand with the bevel flat against the coarse side of the stone. Use the fingers of your other hand to steady the chisel and hold it down against the stone. Using smooth even strokes, rub the chisel back and forth parallel to the surface of the stone (fig. 2-5-36). The entire surface of the stone should be used to avoid wearing a hollow in the center of the stone. Do not rock the blade. The angle of the blade with the stone must remain constant during the whetting process.

After a few strokes, a burr, wire edge, or feather edge is produced. To remove the burr, first take a few strokes with the flat side of the chisel held flat on the fine grit side of the stone. Be careful not to raise the chisel even slightly; avoid putting the slightest bevel on the flat side, for then the chisel must be ground until the bevel is removed.

After whetting the flat side on the fine grit side of the stone, turn the chisel over and place

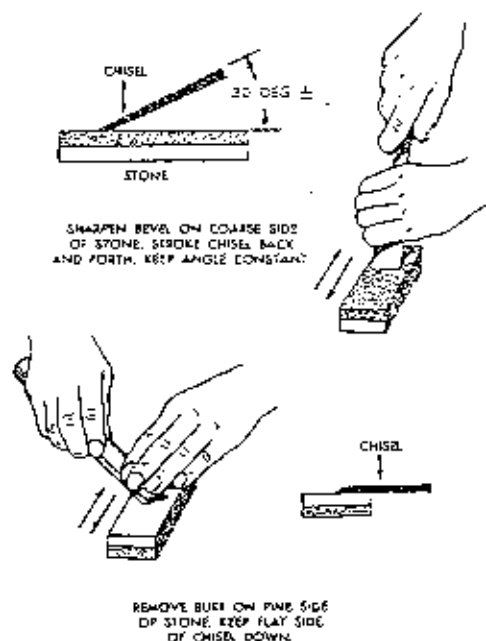


Figure 2-5-36.—Sharpening a woodworker's chisel.

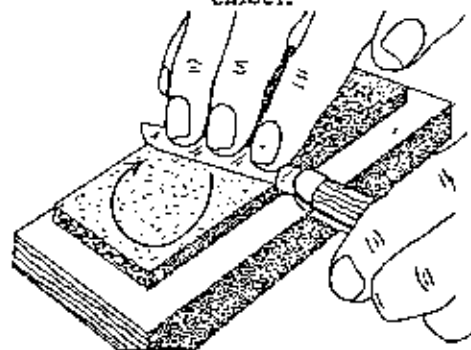


Figure 2-5-37.—Sharpening a pocket knife. the bevel side down and hold it at the same angle as used when whetting on the coarse side of the stone. Take two or three light strokes to remove the burr.

To test the sharpness of the cutting edge, hold the chisel where a good light will shine on the cutting edge. A keen edge does not reflect light in any position. If there are no shiny or white spots it is a good edge.

SHARPENING A POCKET KNIFE ON A SHARPENING STONE

Most pocket knives may be sharpened on a medium or fine grade sharpening stone with a few drops of oil spread on the surface. Hold the handle of the knife in one hand and place the blade across the stone. Press down with the fingers of the other hand and stroke the blade following a circular motion as shown in figure 2-5-37. After several strokes, reverse blade and stroke opposite side, following the same type of motion. Use a light even pressure. A thin blade overheats quickly and can lose its temper. The wire edge or burr that may be left on a knife blade after whetting may be removed by stropping both sides on a soft wood block, canvas or leather.

METAL CUTTING OPERATIONS

The cutting of metal can, in some instances, be a simple operation where accuracy is not important. However, in most cases the cutting of metal is an important and precise job. A large number of tools, both power and hand, have been designed to make metal-cutting operations speedy, economical, and accurate in all kinds of material.

As you advance in your career you will find that there are many special tools designed to do specific jobs. This is true in all ratings but especially true when the rating requires working with metal. Only the skills that require the use of common and versatile metal cutting tools will be discussed in this section.

METAL CUTTING WITH CHISELS

One of the earliest methods of shaping a piece of metal was to chip away the unwanted material with a hammer and chisel. This practice is still common for jobs that are done at the workbench, and where it is not practical to do the work on a machine.

CUTTING METAL ON A FLAT SURFACE

To cut metal on a flat plate, place the metal on a heavy bench plate or similar surface that will serve as backing for the hammer blows. Hold the cold chisel firmly in the cut and slanting slightly away from the direction in which it is cutting. (See fig. 2-6-1). Advance the chisel along the scrap side of the layout line after each hammer blow. Cut through on the first blow for the lighter gages of metal. Heavier gages will require a second or third blow.

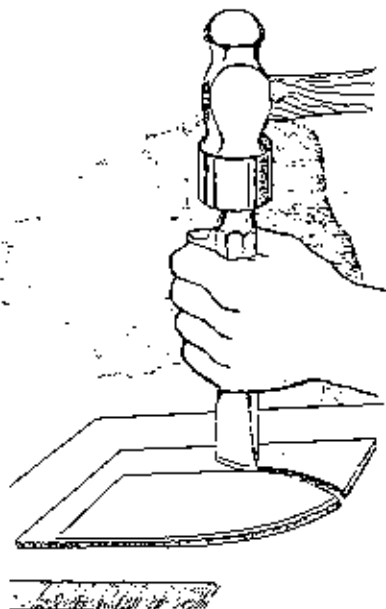


Figure 2-6-1.—Cutting metal on a flat surface.

CHIPPING METAL WITH A CHISEL.

"Chipping" is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies.

Secure the work in a vise with a block under the work to prevent it from slipping. Place canvas or some other type of chipping guard in front of the work to keep flying chips from hitting men working in front of you. Wear goggles to protect your eyes.

For most ordinary chipping with a 3/4-inch chisel, use a 1-pound hammer. Use a lighter hammer for a smaller chisel. Always use a well-sharpened chisel.

Grasp the chisel with one hand, holding the cutting edge to the work and striking the other end of the chisel with the hammer. Keep your eyes on the cutting edge of the chisel to watch the progress of the work. The bevel side of the chisel is the guiding surface, and is held at a very slight angle with the finished part of the work which the cutting edge is touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel and causes the chisel to take a heavier or lighter cut.

To start the chip, the angle 1 in figure 2-6-2A must be great enough to cause the cutting edge to enter the surface of the metal. After the cut has been started, and the desired depth reached, decrease this angle, as shown at 2 in figure 2-6-2B, as the chisel advances or cuts. If you want to decrease the depth of the cut, decrease the angle as shown at 3 in figure 2-6-2C. Notice here that the chisel is riding on the heel of the bevel, causing the cutting edge to "climb out" of the cut.

When chipping wrought iron or steel, wipe the edge of the chisel with an oil-saturated cloth frequently. This will lubricate the contacting surfaces and preserve the cutting edge of the chisel.

After every two or three blows, draw the chisel back slightly from the chip. This tends to ease your muscles and gives you better control over the job.

When chipping case metal, begin at the ends and chip toward the center to keep from breaking corners and edges. Take cuts from 1/16 to 1/32 inch. Leave enough stock so that the surfaces may be finished with a file.

CUTTING WIRE OR ROUND STOCK

When a suitable hacksaw is not available to cut round stock, the chisel may be used.

Mark off a guideline on the stock and place the work on the top face of an anvil or other suitable working surface. Place the cutting edge of the chisel on the mark in a vertical position and lightly strike the chisel with a hammer. Check the chisel mark for the desired cut. Continue to strike the chisel until the cut is made. The last few blows of the hammer should be made lightly to avoid damage to the anvil, supporting surface, or to the chisel.

Heavy stock is cut in the same manner except that the cut is made halfway through the stock; the work is then turned over and the cut finished from the opposite side.

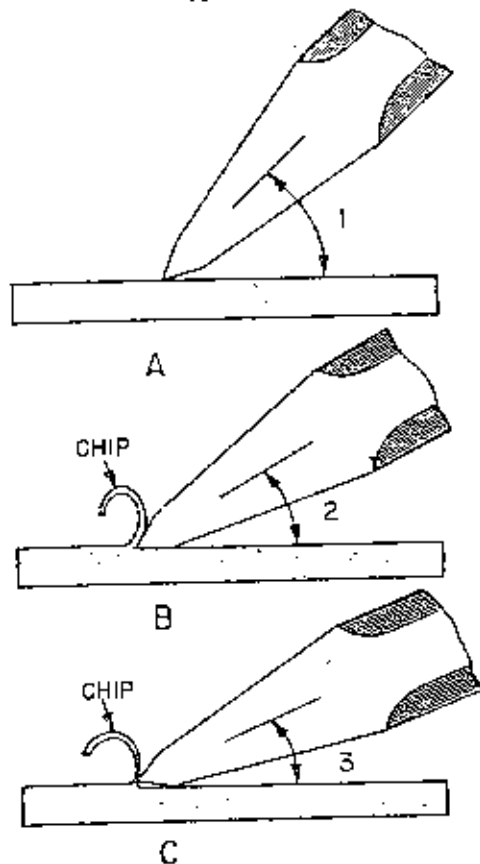


Figure 2-6-2.—Chipping metal with a chisel.

SHEARING METAL IN A VISE

To shear metal in a vise, hold the metal in the bare vise jaws (fig. 2-6-3) in order to provide a shearing action between the rear jaw of

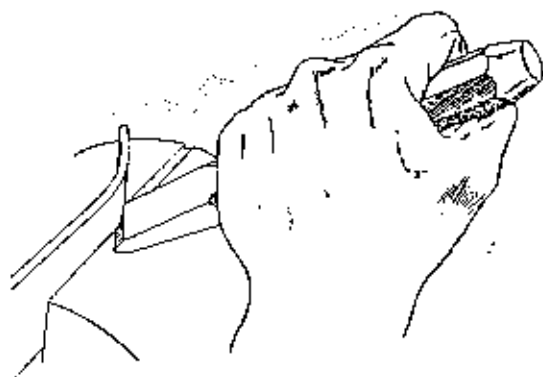


Figure 2-6-3.—Shearing metal with a chisel.

the vise and the cold chisel. Advance the chisel after each blow so that the cutting action takes place in about the center of the cutting edge of the cold chisel. If you are shearing to a line, hold the metal so that the line is just concealed

by the front jaw of the vise. After cutting, it will then be visible along the sheared edge to serve as a guide for grinding or filing.

To cut an internal hole by shearing, hold the metal in the vise as you do for plain shearing. Notice that the cut is being made from a to b in figure 2-6-4A, and that the cutting has stretched the metal at the jaws of the vise. When ab has been cut, hold the metal in the vise along the other lines and cut bc, cd, and da. (See fig. 2-6-4B.)

On the second cut, from b to c, as well as on the next two cuts, the metal will curl back and away from the cut as the cutting proceeds. At the end of the fourth cut, to a point a, which was also the starting point, the scrap will fall away. Then raise the metal in the vise just enough to see the layout line in the clear and dress each sheared edge with a file down to the line. See figure 2-6-4C.

CUTTING OFF A RIVET OR BOLT HEAD

To cut off a rivet or bolt head with a chisel, hold the job in a heavy vise or secure it some other way so that the work will not move. (See fig. 2-6-5A.) Hold the cold chisel with one face of the bevel flat on the surface of the job. Strike

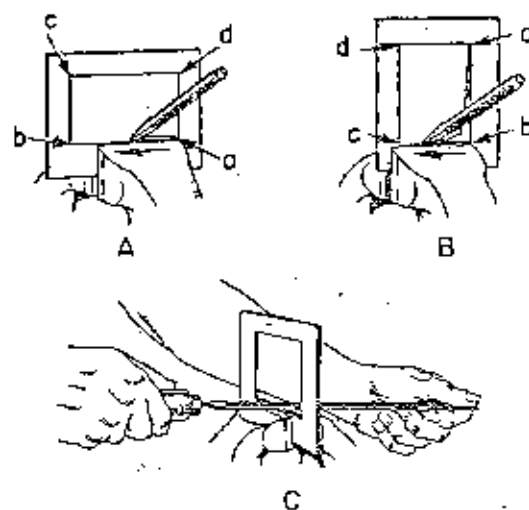


Figure 2-6-4.—Shearing an internal hole in sheet metal.

the head of the chisel with the hammer as you loosely hold and guide the chisel.

To cut off a rivet head with a cape chisel, select a chisel of about the same size as the diameter of the rivet. Cut through the center of the rivet head, holding one face of the bevel flat on the surface of the job, and then sever the center of the head from the shank or body, as shown in figure 2-6-5B.

To cut off a rivet head with a side cutting chisel, commonly called a rivet buster, place the chisel nearly flat on the surface of the work with its single bevel upwards. (The main difference between a rivet buster and a common cold chisel is that the rivet buster has only one bevel.) Drive the cutting edge under the edge of

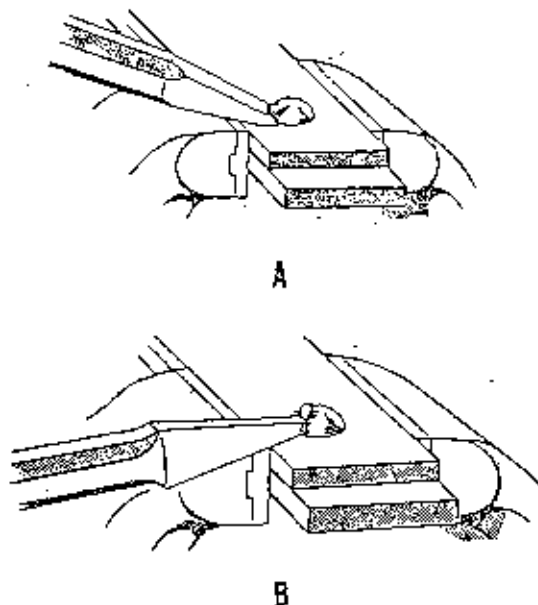


Figure 2-6-5.—Cutting off a rivet head with a chisel.

the rivet head just as you would if you were using a cold chisel. (See fig. 2-6-5A). Notice in figure 2-6-5B that the cutting edge of the chisel has a slight radius which will tend to prevent the corners from cutting undesirable grooves in the surface of the work.

To remove a rivet head (fig. 2-6-7) when there is not room enough to swing a hammer with sufficient force to cut the rivet, first drill a hole about the size of the body of the rivet in and almost to the bottom of the rivet head. Then cut off the head with a cold chisel.

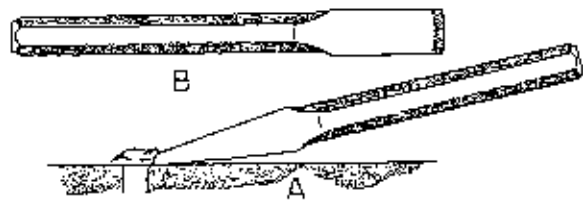


Figure 2-6-6.—Cutting off a rivet head with a side cutting chisel.

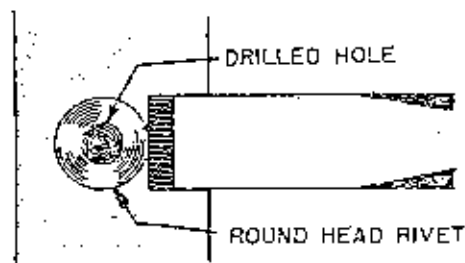


Figure 2-6-7.—Removing a rivet head in a hard to reach position.

CUTTING A GROOVE IN METAL

To cut a groove in metal (fig. 2-6-8), select a half-round chisel the size of the required groove. For small grooves, a round-nose chisel may be used.

As the chisel is driven forward, it will roll a chip ahead of the cutting edge (fig. 2-6-8), cutting a groove in the surface. You can control the depth of the groove by raising or lowering the handle of the chisel. When the handle is lowered, the chisel will tend to "ride out" of the cut on the heel—the part of the chisel just behind the cutting edge.

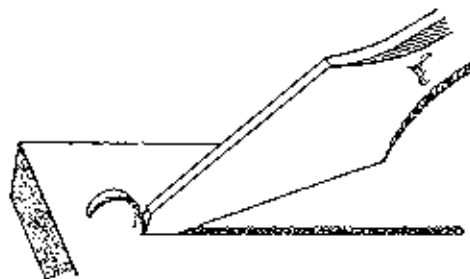


Figure 2-6-8.—Cutting a groove in metal.

CUTTING SHEET METAL WITH SNIPS

To cut large holes in the lighter gages of sheet metal, start the cut by punching or otherwise making a hole in the center of the area to be cut out. With an aviation snips, as shown in figure 2-6-9, or some other narrow-bladed snips, make a spiral cut from the starting hole out toward the scribed circle and continue cutting until the scrap falls away.

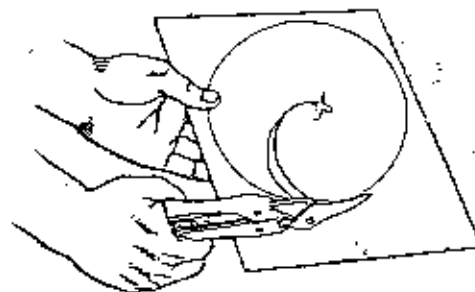


Figure 2-6-9.—Cutting an inside hole with snips.

To cut a disk in the lighter gages of sheet metal, use a combination snips or a straight blade snips as shown in figure 2-6-10. First, cut away any surplus material outside of the scribed circle leaving only a narrow piece to be removed by the final cut. Make the final cut just outside of the layout line. This will permit you to see the scribed line while you are cutting and will cause the scrap to curl up below the blade of the snips where it will be out of the way while the complete cut is being made.

To make straight cuts, place the sheet metal on a bench with the marked guideline over the edge of the bench and hold the sheet down with one hand. With the other hand hold the snips so that the flat sides of the blades are at right angles to the surface of the work. If the blades are not at right angles to the surface of the work, the edges of the cut will be slightly bent and burred. The bench edge will also act as a guide when cutting with the snips. The snips will force the scrap metal down so that it does not interfere with cutting. Any of the hand snips may be used for straight cuts. When notches are too narrow to be cut out with a pair of snips, make the side cuts with the snips and cut the base of the notch with a cold chisel.

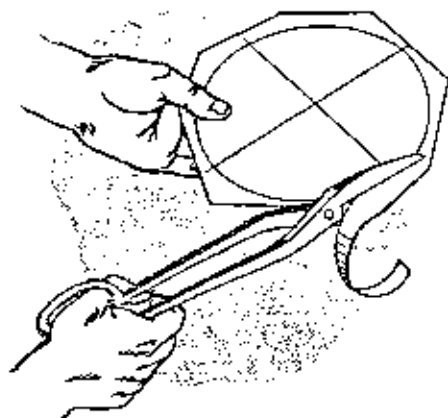


Figure 2-6-10.—Cutting a disk out of sheet metal.

CUTTING HOLES IN METAL WITH PUNCHES

When using a hollow punch to cut holes in metal you should make layout lines on the stock metal. Use a center punch to mark the center of the hole. Scribe the desired circle with a pair of dividers.

When using either a hollow punch (fig. 2-6-11A) or a solid punch, (fig. 2-6-11B), place the stock sheet metal on top of a lead or wooden block. Strike the punch with a hammer to drive it through the metal. The lead or wood block keeps the punch from being damaged.

DRILLING HOLES IN METAL

Before drilling any material, even wood, it is a good idea to center-punch the exact location of the hole. This forms a seat for the drill point and assures accuracy. It is especially important in metal since, without the mark, the drill could "walk off" before it begins to cut into the material.

When drilling sheet metal, place the sheet on a flat surface to prevent the pressure you apply from buckling the sheet. The material you are drilling must be securely clamped.

Always apply pressure on a line which goes straight through the axis of the twist drill. Keep the drill steady and apply enough pressure to keep it cutting. Too much pressure will over-

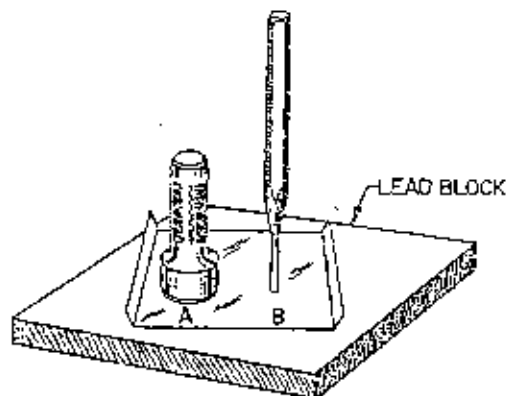


Figure 2-6-11.—Cutting holes in metal with punches.

load the motor; too little pressure will merely cause the drill to "polish" instead of cut. This will quickly dull the cutting edges of the drill. You will know the pressure is correct when the drill bites continuously without loading the drill motor.

Once you have lined up the drill with the hole, keep the drill straight. Side pressure or swaying off the line will enlarge the hole and can break the twist drill.

When drilling large holes, do it in stages, especially if you are using a low-power drill. A pilot hole is a good idea, since it serves as a guide for the larger drill and helps to increase accuracy. Above all, keep the drills sharp.

It is necessary to use a cutting oil to lubricate and cool the drill when drilling steel and wrought iron. Cast iron, aluminum, brass and other metals may be drilled dry, although at high drilling speeds it is advisable to use some medium to cool these metals. Compressed air may be used for cast iron; kerosene for aluminum; oleic acid for copper; sulfurized mineral oil for Monel metal; and water, lard, or soluble oil and soda water for ferrous metals (the soda water reduces heat, overcomes rust, and improves the finish).

HOLDING WORK FOR DRILLING

Most work is held for drilling by some mechanical means such as a clamp, vise, or pliers. When drilling small holes in fairly large pieces of work, it is permissible to hold the work with the bare hands to keep it from turning when the drill begins to cut. Under these conditions, a small drill will break in case it grabs, and the work will not be dangerously spun around at drill speed.

To drill small holes in small pieces with a hand drill or an electric drill, hold the work in a vise so that the axis of the drill is horizontal. See figure 2-6-12A and B. This position provides better control of the drilling and will tend to ensure a hole which will be square with the surface of the work.

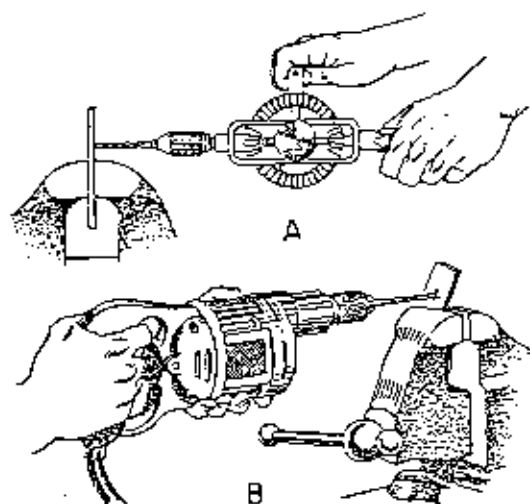


Figure 2-6-12.—Holding small pieces in a vise for drilling.

To drill small holes in small pieces with a drill press, hold the work either with a monkey wrench (fig. 2-6-13), in a drill press vise (fig. 2-6-14), with pliers or locking pliers (fig. 2-6-15), or between V blocks (fig. 2-6-16).

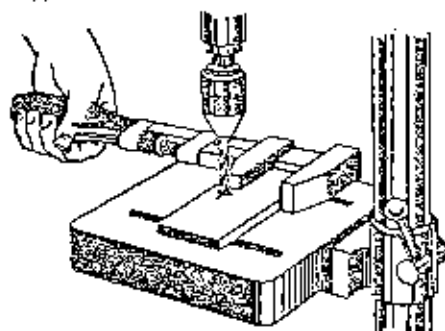


Figure 2-6-13.—Holding work with a monkey wrench.

To drill holes in the end of round stock, place the stock in one of the V-grooves in the stationary jaw of the drill vise as shown in figure 2-6-17. These V-grooves will hold the work so that it is square with the table of the drill press. The drilled hole will then be parallel with the axis of the round stock.

To drill small holes in long pieces (fig. 2-6-18), hold the stock in your left hand and feed the drill with your right hand. Drill over the center hole in the drill press table, if it has one, or place the stock on a flat piece of wood to protect the table. Reduce the feed pressure as the drill reaches the end of its cut to prevent drill breakage.

To drill large holes in large pieces, hold the work by using a step block and clamps, some types of which are shown in figure 2-6-19. Often pieces of metal of the proper thickness are substituted for a step block. A piece of metal with a hole drilled near one end makes a satisfactory substitute for a clamp.

To hold work with clamps and step blocks, the gooseneck clamp may be used, as in figure 2-6-20, to provide clearance for such obstructions as the nut below the overhang on the job

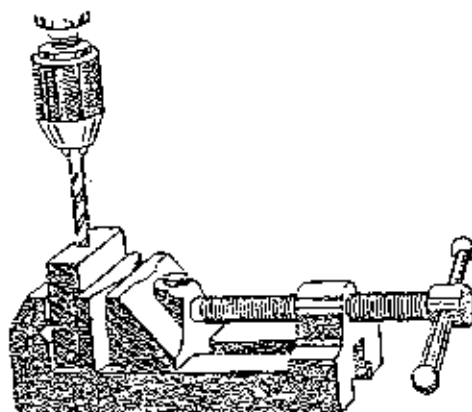


Figure 2-6-14.—Holding work with a drill press vise.

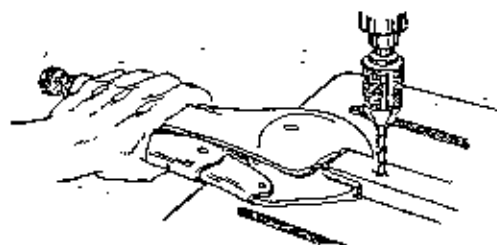


Figure 2-6-15.—Holding work with a pair of locking pliers.

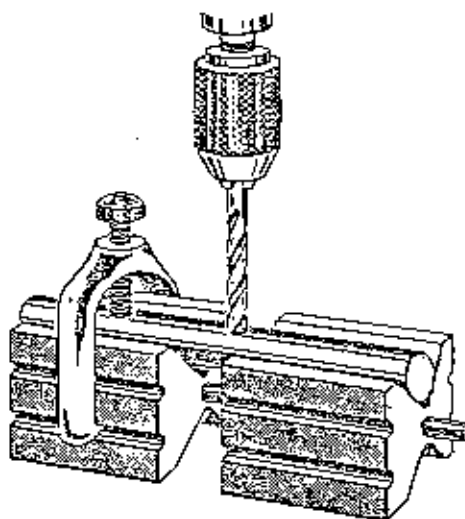


Figure 2-6-16.—Holding work in V-blocks.

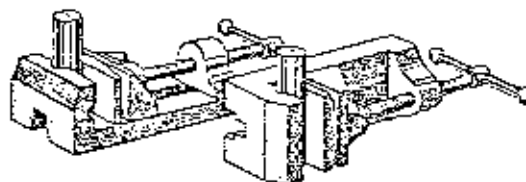


Figure 2-6-17.—Holding work to drill holes in end of round stock.

shown. Notice that the body of the clamp is approximately parallel with the surface of the drill press table and that the bolt is held close

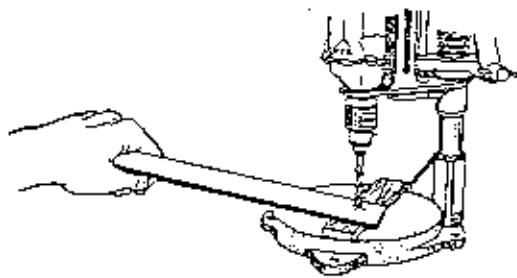


Figure 2-6-18.—Holding a long piece for drilling a small hole.

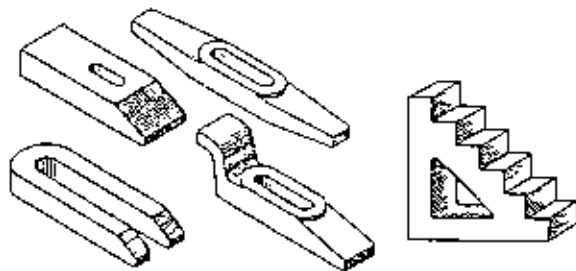


Figure 2-6-19.—Step block and clamps.

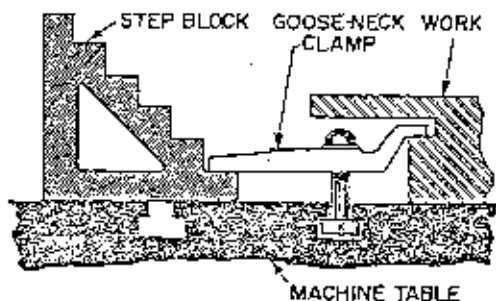


Figure 2-6-20.—Holding work with step block and clamp for drilling.

to the work rather than close to the step block. This provides the most favorable mechanical advantage. Usually two or more clamps are used on each setup.

To hold thin metal for drilling, place it on a block of wood to provide support directly beneath the hole. This will help minimize drill breakage when the feed pressure is applied. Then secure the C-clamp as shown in figure 2-6-21, and drill through the metal and into the wood. Stop drilling when wood chips appear so as not to damage the drill press table. Some tables have no center hole, or, if there is a center hole, it may not be lined up directly below the drill.

SPEED AND FEED FOR DRILLING

The **SPEED** of a drill is the distance the drill would roll if it were placed on its side and rolled at a given rpm for 1 minute. This speed is usually expressed in feet per minute (fpm). The correct cutting speed for a job depends upon the

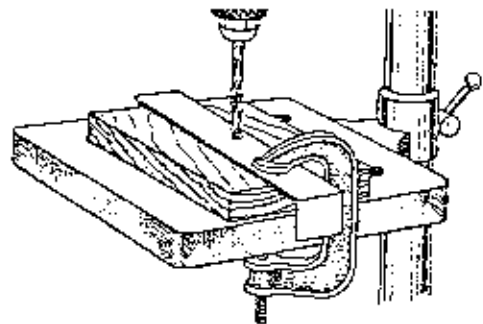


Figure 2-6-21.—Holding thin gage metal for drilling.

degree of hardness of the metal, the impurities in the metal, and the type of drill used. The following speeds are recommended when using high-speed drills.

Alloy steel	50-70 fpm
Machine steel	70-100 fpm
Cast iron	70-150 fpm
Brass	200-300 fpm

Carbon steel drills should be run at approximately one-half the speeds given above. With practice, you will be able to determine for yourself the correct speed for each piece of work.

The speed of the drill press is given in rpm. Tables giving the proper rpm at which to run a drill press for a particular metal are usually available in the machine shop, or they may be found in machinists' handbooks.

The **FEED** of a drill is the rate of entry into the work during each revolution. Feed is expressed in thousandths of an inch per revolution. In general, the larger the drill, the heavier the feed that may be used.

COUNTERBORING HOLES IN METAL

Counterboring is the operation of boring a second hole, larger in diameter than the first but concentric with it. A tool known as a counterbore is used for this operation. (See fig. 2-6-22.) The small diameter on the end of the tool, known as a pilot, keeps the counterbore concentric with the original hole. Pilots of different sizes are interchangeable to fit various sizes of holes.

Counterbores are also used for spot facing. In this operation, usually performed on castings, the objective is to remove enough material to provide a flat surface around a hole to accommodate the head of a bolt, nut or screw.

Counterbores for screw holes in metal are available in the usual twist drill sizes from 1/4" to 3", in either taper or straight shanks. They are generally made in sets, and a set may include counterbores ranging in size from 1/4 inch to 1 inch by 16ths. Pilots will be included which increase in size by 32ds in the smaller



Figure 2-6-22.—Counterboring tool with pilot.

sizes and by 16ths in the larger sizes. Because the pilots are removable, various combinations of counterbores and pilots are possible. In figure 2-6-23A and B are the same size counterbores with pilots of different sizes as indicated. B and C are the same size pilots with counterbores of different sizes as indicated.

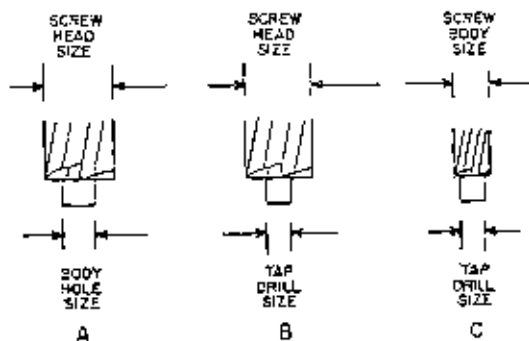


Figure 2-6-23.—Various combinations of counterbores and pilots.

A counterbore can be used to counterbore, or to spot-face, or to drill holes in metal which is too thin to drill with a twist drill.

Figure 2-6-24 is a drawing of a counterbored hole for a $\frac{3}{8}$ " fillister head or an internal chucking head screw. Here the pilot size is $\frac{3}{8}$ ", which is the body hole size, and the body size of the counterbore is equal to the nominal diameter of the head of the screw.

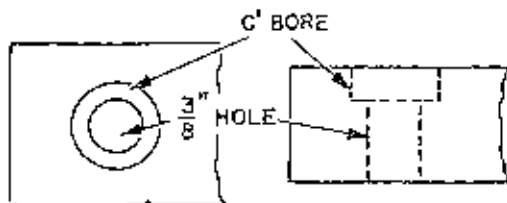


Figure 2-6-24.—Drawing of a counterbored hole for a fillister head screw.

In figure 2-6-25A, the surface of the casting has been spot-faced to make it clean and square with the hole and seat the head of the cap screw properly.

To spot-face the surface of a casting, select a counterbore that will be larger than the greatest diameter of the head of the cap screw. This is necessary so that the entire bottom of the

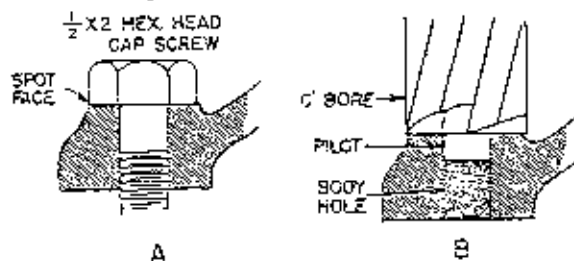


Figure 2-6-25.—Spot facing a surface on a casting.

screw head will rest on the spot-faced surfaces. See figure 2-6-25B. Then select a pilot the size of the screw body hole, insert it in the counterbore, and proceed with the counterboring until the seating surface is cleaned up.

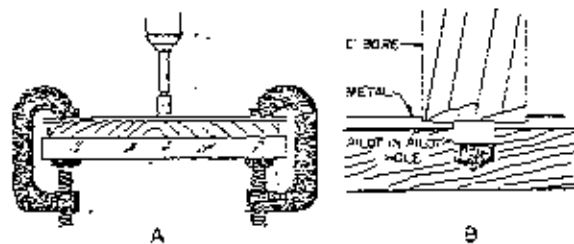


Figure 2-6-26.—Counterboring a hole in thin metal.

Figure 2-6-26 shows how a piloted counterbore is used to bore holes in thin metal. Secure the stock over a block of wood on the drill press table, as shown in figure 2-6-26A, and drill the pilot hole through the metal and into the wood. Then follow up with the counterbore, using a pilot to fit the pilot hole, and bore with the counterbore until the larger hole has also been bored through the metal and into the wood. (See fig. 2-6-26B.)

THREADS AND THREAD CUTTING

Threads are helical ridges cut into screws, nuts, bolts, or the walls of a hole, so that the action of turning the screw, nut, or bolt gives it endwise as well as rotary motion.

There are many types of threads, each designed for a specific type of work. The most common type of bolt threads in use today, however, is the American National form of threads of which there are two series: coarse thread series and fine thread series. The fine threads are of the same general shape as the coarse ones, but they are smaller and there are more of them per inch. Nuts with fine threads may be drawn up tighter than those with coarse threads, and they will not shake loose so easily.

Machine screw threads are of the same general shape as bolt threads, but they are much smaller. Machine screws are used in small machines and apparatus such as small motors, electric fans, and carburetors.

Pipe threads are used on pipe and pipe-and-tubing connections on engines, motors, and other machines. Pipe threads have a taper of $\frac{1}{16}$ inch per inch of length. Since the threaded end of a pipe is tapered, the farther it is screwed into a fitting, the tighter the joint becomes. This makes it possible to make a tight joint without having any tension or end pull on the pipe. Since bolt and machine threads are straight they do not tighten until they are drawn up against the part being held.

Because of the system of indicating pipe sizes, pipe threads are much larger than the corresponding size of bolt threads. The size of pipe is designated by its inside diameter. A

1/2-in. bolt die cuts threads on the outside of a rod or bolt whose outside diameter is 1/2-in.; a 1/2-in. pipe die cuts threads on the outside of a pipe whose inside diameter is 1/2-inch. The pipe die, therefore, is much larger.

It is common practice to indicate the size of a bolt thread by two numbers, the first being the diameter of the bolt and the second the number of threads per inch. For example, a 3/8-16 thread would be for a 3/8-in. bolt which has 16 threads per inch. The size of a machine-screw thread, or a tap or die for cutting it, is designated by two numbers in the same manner as bolt threads, the first number being the size of the screw and the second the number of threads per inch. For example, an 8-32 thread is for a No. 8 screw which has 32 threads per inch.

DETERMINING THE PROPER SIZE TAP DRILL FOR PARTICULAR TAPS

If a threaded hole is to be made in a piece of metal, a hole of suitable size must first be drilled. The hole must be somewhat smaller than the size of the bolt to be screwed into it, usually 1/16 in. smaller for bolts 1/4 to 1/2 in. in size.

The best method to determine the exact size of tap drill to use is to refer to the American National Form Threads chart in appendix of this course. A chart similar to this generally is included with a set of taps and dies.

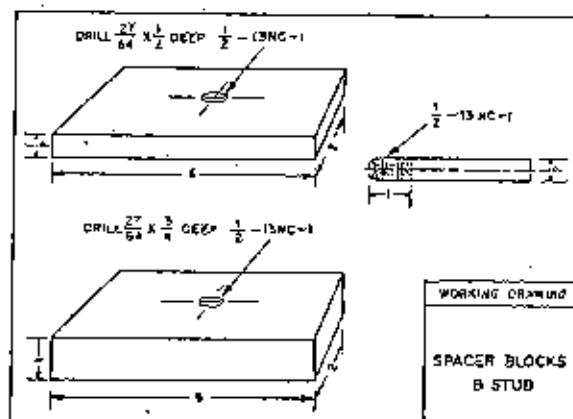


Figure 2-6-27.—A working drawing for tapping and cutting threads.

The working drawing shown in figure 2-6-27, specifies a 1/2 in. 13 National Coarse (NC) thread to be tapped in a through hole in one part (1/2 in. deep hole in 1/2 in. stock). The same thread is to be tapped in a blind hole in another part (3/4 in. deep hole in 1 in. stock). The 1/2 in. round stock is to be threaded with this same thread to fit the tapped holes.

Refer to the chart in appendix and run down the first two columns until you locate 1/2-13 N.C. Follow this line to the right until you come to the tap drill size, 27/64 in. which will produce

approximately a 75 percent full thread. Use the 27/64 in. drill to drill a through hole in the 1/2 in. block and a hole 3/4 in. deep in the 1-in. block as required by the working drawing.

When the tap hole is the right size, it is a little larger than the root diameter of the tap as shown in figure 2-6-28. The tap will cut a thread in the work which is only 75 percent as deep as the thread on the tap. The other 25 percent of the depth of thread on the tap provides clearance between the tap hole and the root diameter of the tap. (See fig. 2-6-28.) This makes tapping easier.

If the tap drill selected is oversize, the tap hole will be oversize, and the tap can cut only shallow threads in the work. (See fig. 2-6-29.)

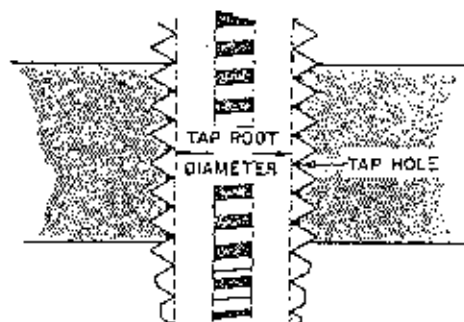


Figure 2-6-28.—Proper size drilled hole for tapping.

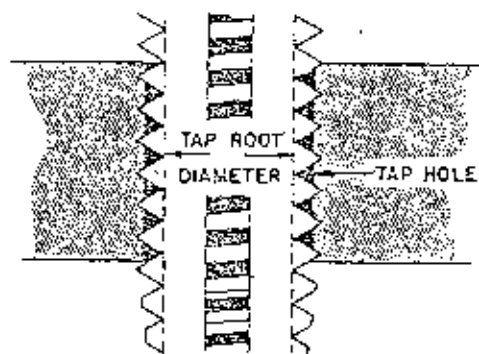


Figure 2-6-29.—Oversize drilled hole for tapping.

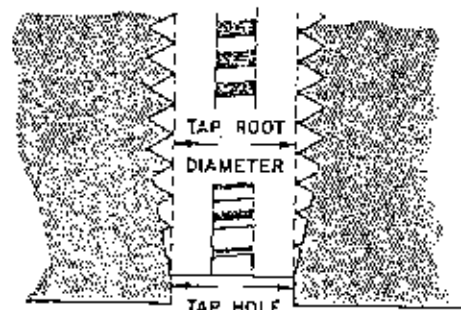


Figure 2-6-30.—Undersize drilled hole for tapping.

With less than a full 75 percent depth of thread, stud or capscrew threads usually strip.

If the tap drill selected is undersize, the tap hole will be undersize, being perhaps equal to the root diameter of the tap as shown in figure 2-6-30. Then there will be no clearance, and the tap will turn hard, tear the threads, and probably break.

CUTTING MACHINE THREADS WITH TAPS

A 50-50 mixture of white lead and lard oil, applied with a small brush, is highly recommended as a lubricant when tapping in steel. When using this lubricant, tighten the tap in the tap wrench and apply the lubricant to the tap. Start the tap carefully with its axis on the center line of the hole. The tap must be square with the surface of the work, as shown in figure 2-6-31.

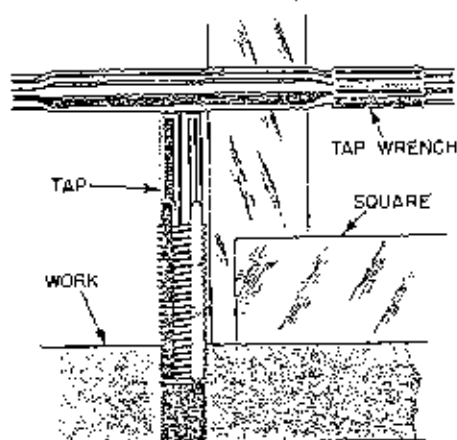


Figure 2-6-31.—Using a square to ascertain a tap is square with the work.

To continue tapping, turn the tap forward two quarter turns, back it up a quarter turn to break the chips, and then turn forward again to take up the slack. Continue this sequence until the required threads are cut. Lard oil alone is sometimes used for lubrication, and is conveniently applied from an oil can. After you cut for the first 2 or 3 full turns, you no longer have to exert downward pressure on the wrench. You can tell by the feel that the tap is cutting as you turn it. Don't permit chips to clog the flutes or they will prevent the tap from turning. When the tap won't turn and you notice a springy feeling, stop trying immediately. Back the tap up a quarter turn to break the chips, clean them out of the flutes with a wire as shown in figure 2-6-32, add some more lubricant, and continue tapping. When the tap has cut threads through the hole, the tap will turn with no resistance.

To tap a blind hole, start with the taper tap. For a blind hole you will need all three types—the taper, plug, and bottoming taps. Be sure they are the size and thread series you need, and that the tap hole is the size called for by the working

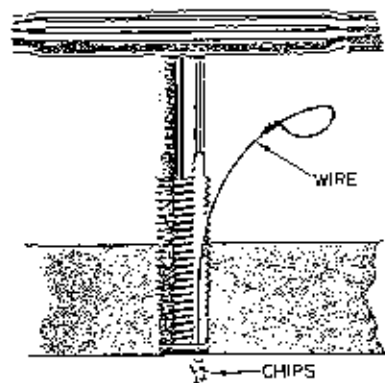


Figure 2-6-32.—Using a wire to clear chips from flute of a tap, drawing and the chart in appendix.

Begin with the taper tap. Handle it as described and shown before. Figure 2-6-33A shows the taper tap just starting to cut. In figure 2-6-33B it has cut a little farther. In figure 2-6-33C it has bottomed in the hole after having cut several full threads near the top of the hole. This completes the work to be done with the taper tap.

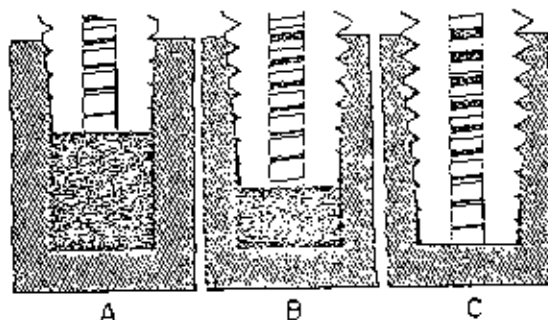


Figure 2-6-33.—Tapping a blind hole with a taper tap.

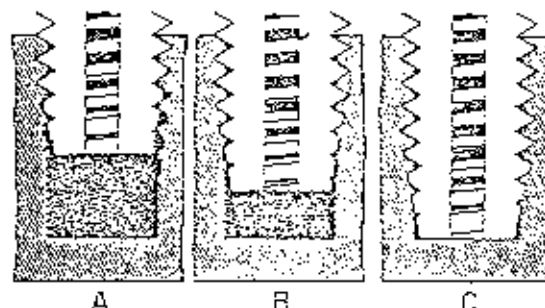


Figure 2-6-34.—Tapping a blind hole with a plug tap.

In figure 2-6-34A the plug tap has entered the hole a few full threads cut by the taper tap. At figure

2-6-34B it has continued these threads a little farther down into the hole. At figure 2-6-34C it has bottomed in the hole. This is all the work that you can do with the plug tap. It has cut full threads about halfway down the tap hole before bottoming.

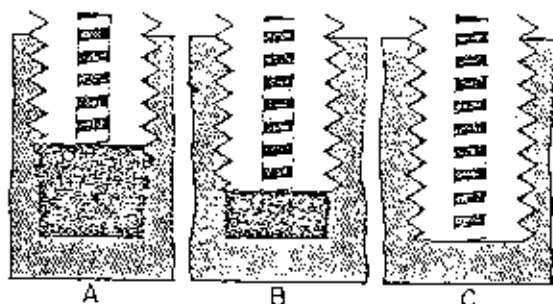


Figure 2-6-35.—Finish tapping a blind hole with a bottoming tap.

In figure 2-6-35 the bottoming tap has been substituted for the plug tap. In figure 2-6-35A it has been run down the full threads cut by the plug tap and is ready to cut more full threads. In figure 2-6-35B it has cut a few more threads, and in figure 2-6-35C it has bottomed in the hole. The blind hole has now been completely tapped.

Because these threads are being tapped in a blind hole, chip removal must be done differently. To remove chips, back the tap completely out of the hole very frequently, invert the stock, if possible, and jar out the chips or work them out of the hole with a wire while the stock is in the inverted position. If the work cannot be inverted, blow out the chips with air. Chip removal in tapping blind holes is much more difficult to do and is very important because chips will fall ahead of the tap through the flutes and accumulate in the bottom of the blind hole. Until these chips are removed, none of the three taps can complete its work. In tapping blind holes alternate with tapping and chip removal until each of the three taps bottom in the blind hole.

When you have finished using the three taps, brush the chips out of their teeth, oil them well with lubricating oil, wipe off the surplus oil, and replace them in the threading set.

CUTTING MACHINE THREADS WITH DIES

To cut threads on a piece of round stock—1/2-13 N.C. on a 1/2-inch rod in this case—first grind a chamfer on the end of the rod as shown in the working drawing in figure 2-6-27. Then hold the rod vertically in the vise to cut the threads. The working drawing in figure 2-6-27 calls for a 1/2-13N.C.-1 thread. The figure 1 after the N.C. indicates that a class 1 fit is required. A class 1 fit is a loose fit. The fit is controlled while threading the round stock. We tap the threads in the hole first as there is

no way to adjust a tap. However, as threading dies are usually adjustable, we can control the fit of the threaded rod in the tapped hole by adjusting the threading die.

The adjustable round split die shown in figure 2-6-36 has an adjusting screw at A. By

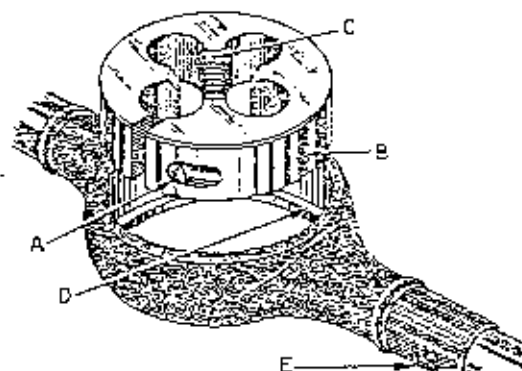


Figure 2-6-36.—Assembling an adjustable round split die to die stock.

tightening this screw and spreading the die slightly, it will cut less deeply into the rod and the fit in the tapped hole will be tighter. The shallow hole at B is placed in the die stock opposite the adjustable handle E and serves as a drive hole. Also, when the adjustable handle is tightened, it holds the split die together and against the adjusting screw to maintain the setting while the die is cutting. The threads or cutting teeth of the die are chamfered or relieved at C to help start the die squarely on the round stock. The die is put into the die stock with the face with the unchamfered teeth against the shoulder, D.

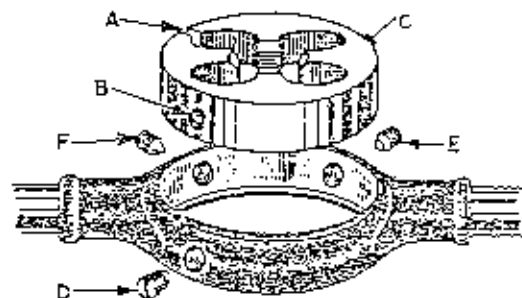


Figure 2-6-37.—Assembling a plain round split die to die stock.

Figure 2-6-37 is a plain round split die and die stock. At A, where the die is split, there is no adjusting screw. There are shallow holes at B and C, on both sides of the split, opposite which there are setscrews in the die stock at D and E. F is the adjusting screw which is pointed and enters the split A in the die. D and E are the holding setscrews. They have flat points and are tightened after the setting is made with F. D and E hold the adjustment and furnish the drive as they enter the shallow holes B and C shown in figure 2-6-37.

Figure 2-6-38 shows a section of the die in the die stock and its relation to the chamfer on the end of the work. The taper on the face of the die will accept the chamfer on the end of the work to start the threads square with the common center line.

To thread the work, brush some 50-50 white lead and lard oil on the rod. Start the die square with the work. Hold one handle with each hand, apply downward pressure, and turn clockwise until you feel the thread has been started. When the die has started to cut, rotate the die stock

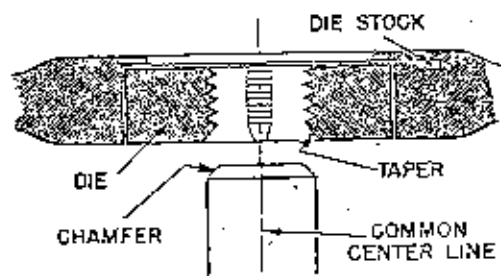


Figure 2-6-38.—Position of diestock in relation to chamfer on end of work.

two quarter turns, back it off one quarter turn to break the chips, and repeat the cutting (see fig. 2-6-39). When you have cut enough threads so that the rod comes through the back of the die, remove the die and try the rod in the tapped hole.

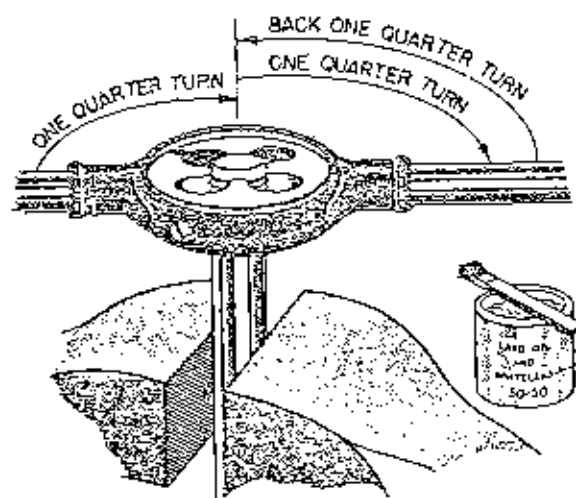


Figure 2-6-39.—Cutting outside threads on round stock.

Adjusting a threading die to produce a thread of the proper fit is a trial-and-error procedure. This was a trial run. If the fit is too loose, cut off and discard the portion of the rod that you threaded. Then expand the die by tightening the pointed setscrews (or the adjusting screw) so that the die will cut shallower threads on the rod and produce a tighter fit.

If the fit is too tight, it will not be necessary to discard the threaded portion of the rod. Contract the die by backing off (loosening) the pointed setscrew (or the adjusting screw) to decrease the size of the split in the die. This will cause the die to remove more metal, when cutting, and produce a looser fit. Then run the die down the cut threads that were too tight. Now test the fit again by turning the threaded end into the tapped hole.

When you have finished the threading job, remove the die from the die stock, carefully clean out all the loose chips, and apply plenty of oil. Wipe off the surplus oil and put the die and die stock away in the threading set where they will be protected and ready for the next job.

RECONDITIONING MACHINE THREADS

To recondition machine threads, when the damage is not serious, the general practice is to select the proper threading die, one type of which is shown in figure 2-6-40A. Put it in a die stock, and run over the threads that are damaged. For steel, lubricate with a 50-50 mixture of white lead and lard oil, lard oil alone, or lubricating oil if the others are not available. Use no lubricant for brass and copper. Start the die with the chamfered face of the die which is shown in the figure.



Figure 2-6-40.—Two thread reconditioning tools.

The screw and bolt rethreading die, shown in figure 2-6-40B, is designed especially for reconditioning threads. The six sets of cutting teeth, in place of the customary four sets on a threading die, provide better alignment while the die is recutting damaged threads. Turn this rethreading die with any type of wrench or hold the die in a vise and turn the threaded piece through it.

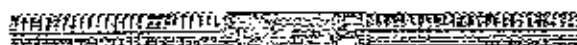


Figure 2-6-41.—Thread restorer.

When only the first thread or the first 2 or 3 threads are damaged, and a perfect thread is not absolutely necessary, a three-square file can be used to touch up the tops of the damaged threads. A knife file will get down a little deeper into the threads when necessary.

The thread restorer shown in figure 2-6-41 resembles a square file. Each face is designed to match a certain pitch-screw thread. Two sizes of this tool are available, each one covering eight different machine-thread pitches. Together they cover a range of from 9 threads per inch through 32 threads per inch. Use this thread restorer as you would a file, maintaining the proper angle (that of the threads) as you go over the damaged threads.

Tools of this type are available for external pipe threads as well as for machine threads. The thread restorer for internal pipe threads, however, is similar to a tap. This type of thread restorer, whether internal or external, removes metal. Therefore, the thread that remains as a restored thread will not be a perfect or full thread. Where the crest of the original thread was battered over, the crest of the restored thread will be noticeably flat. Threads restored in this manner are, for practical purposes, as strong as new threads. They will again enter a nut or tapped hole.

Another type of thread restorer is shown in the 2" to 4" size in figure 2-6-42. This tool is not designed to cut new threads, but only as a maintenance and repair tool. Its action is a reforming action and not a cutting action. Therefore no metal is removed from the thread that is being forced back to its original shape. Only four sizes of this tool are necessary to cover thread diameters from one-quarter inch to 6 inches. A fifth size takes all diameters from 6 to 12 inches, inclusive. Each size will fit any pitch, left- or right-hand threads, standard pipe or machine thread, within the size limits specified, and no change of blades or dies is necessary. This restorer will not work on Acme threads.

To operate this thread restorer, simply slip it over the threads with the arrow on top, or toward you. Then tighten the jaws or blades

to a snug fit into the threads close to the back of the thread where no damage has been done. Then, just as you would remove a nut, turn the tool counterclockwise in the direction of the arrow on right-hand threads. To restore left-hand threads, first flop the tool over so that the face of the tool having the arrow is away from you. Then, after bringing the jaws up snug, run the tool off of the left-hand threads by turning it clockwise so that it will move toward you. Notice that this type of thread restorer normally works from the bottom or back of the thread out toward the end, restoring the threads as it progresses.

In most cases, restorers slide easily over key ways and milled flats on threaded parts. It may be found that the milled flat is rather wide on large-diameter jobs. In such cases threads can still be restored and the tool will negotiate the flat if you will clamp a half round piece of soft wood on the flat and operate the tool as directed. When this is necessary, it is usually on work of 2-inch diameter or larger. When used on studs or bolts having cotter pin holes, a small wooden plug in the hole will avoid breaking teeth. Keep the restorer clean and well oiled both in use and in storage.

CUTTING INTERNAL PIPE THREADS

Pipe threads are tapered threads to provide an airtight and liquidtight joint. A 3/8" machine thread tap and a 3/8" pipe thread tap are compared in figure 2-6-43 to show their differences. The 3/8" machine thread tap will cut machine threads in a hole so that a 3/8" cap screw, having the same thread, can be screwed into the hole. The 3/8" pipe thread tap will cut pipe threads in a hole so that a 3/8" threaded pipe can be screwed into the hole. Because pipe diameters are measured and given as inside diameters, and the wall

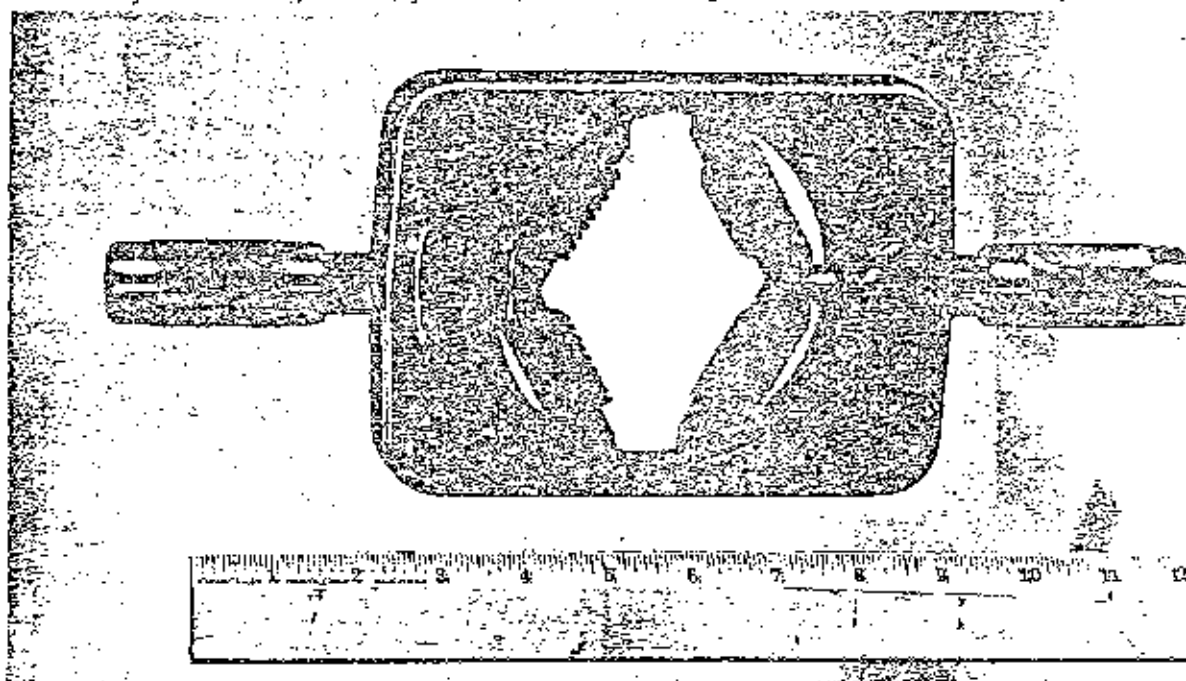


Figure 2-6-42.—Adjustable type thread restorer.

thickness of the pipe must be taken into consideration, the 3/8" pipe thread tap in figure 2-6-43 is noticeably larger than the 3/8" machine thread tap. It should also be noted that the pipe thread tap is tapered, but the machine thread tap is not.

The N. P. T., which formerly stood for National Pipe Thread, is still used as a carryover and now refers to the new name for the same thread, American Standard Taper Pipe Thread. This standard taper is 3/4" per foot.

To select the proper tap drill for the pipe tap that you will use to tap a hole to take a

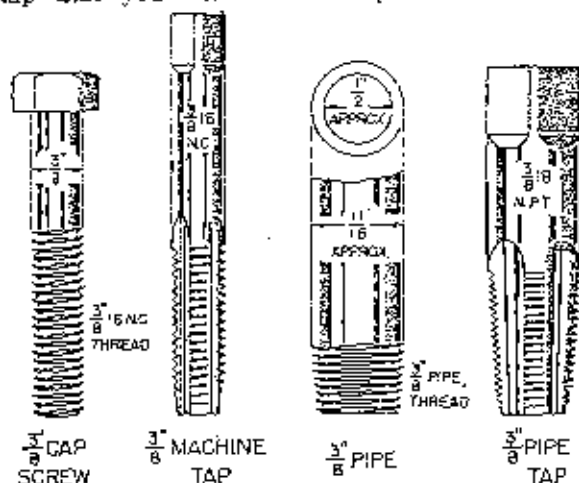


Figure 2-6-43.—Comparison of machine thread tap and pipe thread tap.

given size of threaded pipe, refer to figure 2-6-44. For example, if you want to drill and tap a hole to take a 3/8" pipe thread, find the 3/8" pipe tap in the Pipe Tap Size column. Opposite this, in the Tap Drill Size column, is 19/32", the proper tap drill to use for a 3/8" pipe tap.

Pipe Tap Size	Tap Drill Size	Pipe Tap Size	Tap Drill Size
1/8"	63/64"	2"	2 1/8"
1/4"	7/16"	2 1/2"	2 5/8"
3/8"	13/32"	3"	3 1/8"
1/2"	21/32"	3 1/2"	3 5/8"
5/8"	1 1/8"	4"	4 1/8"
1"	1 1/16"	4 1/2"	4 5/8"
1 1/4"	1 5/8"	5"	5 1/8"
1 1/2"	1 3/4"	6"	6 1/8"

Figure 2-6-44.—American Standard pipe tap drill sizes.

To cut internal pipe threads, drill a tap hole in the stock to be tapped and, following the suggested procedure for tapping machine threads given elsewhere in this book under the heading Cutting Machine Threads With Taps, run the pipe tap into the tap hole. Notice that the first few threads on the pipe tap are ground away. This makes starting easier. Plenty of lard oil is the standard lubricant for steel. Tap copper

and brass with no lubricant. The depth to which it is desirable to tap pipe threads is usually determined by turning the threaded pipe into the tapped hole for a trial. As shown in figure 2-6-45, the last few threads on the pipe should still be visible when the pipe is drawn up tight in the tapped hole. Reference to the table in figure 2-6-46 shows the values of dimension A for various sizes of pipe up to 12".



Size of Pipe, Inches	Dimension A, Inches	Size of Pipe, Inches	Dimension A, Inches	Size of Pipe, Inches	Dimension A, Inches
1/8"	1/8"	1 1/2"	1 1/8"	5"	1 1/4"
1/4"	1/4"	2"	1 1/4"	6"	1 1/4"
3/8"	3/8"	2 1/2"	1 1/4"	7"	1 1/4"
1/2"	1/2"	3"	1 1/4"	8"	1 1/4"
5/8"	5/8"	3 1/2"	1 1/4"	9"	1 1/4"
1"	1"	4"	1 1/4"	10"	1 1/4"
1 1/4"	1 1/4"	4 1/2"	1 1/4"	12"	1 1/4"

Figure 2-6-45.—Length of thread on pipe required to make a tight joint.

Nominal Size	Outside Diameter	Nominal Size	Outside Diameter
1/8"	1 1/8"	3 1/2"	4"
1/4"	1 1/4"	4"	4 1/2"
3/8"	1 3/8"	4 1/2"	5"
1/2"	1 1/2"	5"	5 1/2"
5/8"	1 5/8"	6"	6 1/2"
1"	1 3/4"	7"	7 1/2"
1 1/4"	1 7/8"	8"	8 1/2"
1 1/2"	1 7/8"	9"	9 1/2"
2"	2 1/4"	10"	10 1/2"
2 1/2"	2 3/4"	11"	11 1/2"
3"	3 1/2"	12"	12 1/2"

Figure 2-6-46.—Approximate O.D. of standard wrought iron pipe.

The general practice in tapping holes for pipe threads is to drill the proper size tap hole and then start the pipe tap right into the tap hole. Some men recommend using a pipe reamer, especially when large deep holes are to be tapped. A pipe reamer has a 3/4" per foot taper as a pipe tap. A reamed pipe tap hole would have the same shape as the pipe tap, and therefore would make tapping easier and reduce wear on the tap.

CUTTING EXTERNAL PIPE THREADS

Usually, both ends of a pipe are threaded with external pipe threads. Notice, in all the figures showing pipe threads, that they are V-shaped. The standard 3/4" taper per foot of pipe threads is equal to 1, 16" per inch. There-

fore, the taper of the threads on each side of the pipe is $1/32$ " taper per inch. This taper cannot be changed. This produces a tight joint. The angle between sides of the threads is 60° , and several threads on the end of the pipe are perfect threads. The next few have V-bottoms but flat tops, and the last few threads have both flat tops and bottoms. Each size of pipe has a certain number of threads per inch, built into the pipe taps and dies.

Adjustable pipe dies have a reference mark on each die which, when lined up with the corresponding reference mark on the die stock, will give a standard-size thread. You adjust the dies one way or the other from the reference mark to cut a thread with the fit you want.

To cut external threads on iron pipe, first determine its nominal size. Nominal size means the "name size" of the pipe such as $1/8$ ", $3/4$ ", and so on. Except in the sizes below 1", nominal sizes correspond closely to inside diameters. For 1" pipe and larger, measure the I.D. with your rule, to the closest $1/32$ ", and you will have nominal size. For sizes below 1", you can determine nominal size by measuring the O.D. to the nearest $1/32$ " and reading the corresponding nominal size on the chart in figure 2-6-46. This method can also be employed for sizes 1" and above in lieu of the I.D. measurement.

To begin cutting, put the die stock on the pipe so that the pipe passes through the guide and enters the tapered face of the pipe die. Turn the die stock clockwise for right-hand threads, applying pressure only when starting. It is not necessary to turn the die back and forth as you do when cutting machine threads. Pipe-threading dies can cut continuously because they cut only as many threads on the pipe as there are on the die itself and because there is plenty of room in a pipe die for the chips to escape. After the die has taken hold, it will feed itself. When cutting threads on steel pipe, apply lard oil to the pipe and die where the cutting is actually taking place. Continue turning until the end of the pipe has gone through the die and is flush with the near face. See figure 2-6-47.

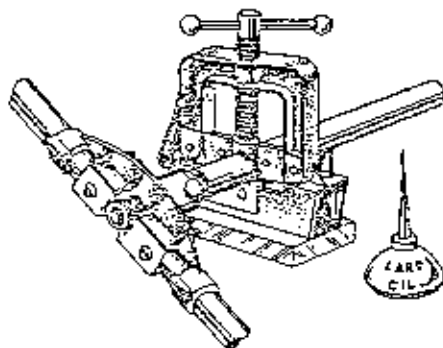


Figure 2-6-47.—Threading an external pipe thread with a pipe die.

This will give you the length of thread called for in the table in figure 2-6-45. Notice that, in the assembled pipe joint in figure 2-6-45,

several threads remain on both pipe and fitting to permit further tightening should a leak develop. Dimension A in figure 2-6-45 is the length of thread on pipe required to make a tight joint.

REAMING OPERATIONS

Reaming operations are jobs that smoothly enlarge drilled holes to an exact size and finish the hole at the same time. A hole that has been made by drilling is usually slightly oversize. This is quite satisfactory for holes in which bolts or rivets are placed. When greater accuracy and a smooth finish are required, the hole is first drilled undersize and then finished by reaming. Reamers are also used to remove burrs from the inside diameters of pipe and drilled holes.

Most reaming operations are done by hand-turning the reamer; however, some reamers are designed for operation on power machines. Never use a reamer that is designed for hand-reaming on a power machine as the handreamers cannot withstand the higher speeds.

REAMING A HOLE WITH A SOLID STRAIGHT REAMER

A solid straight-hole reamer is used for most work, since it is the most accurate and rugged

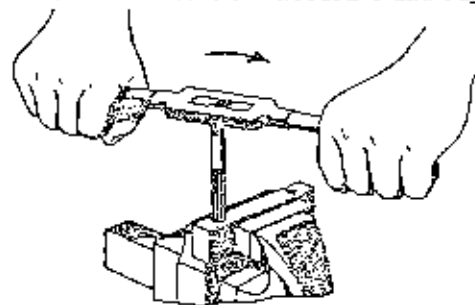


Figure 2-6-48.—Using a tap wrench to turn a hand reamer.

of the straight-hole reamers. The straight-hole handreamer is turned by means of a tap wrench that is tightened on the square end of the reamer shank. (See fig. 2-6-48.) Secure the work in a vise so that the hole to be reamed is perpendicular to the top of the vise jaws. Position the reamer at the top of the hole (fig. 2-6-49). Straight-hole reamers have a slight taper at the end so that they will fit into the hole easily. Turn the wrench clockwise very slowly until the reamer is centered in the hole.

After the reamer is centered in the hole, turn the wrench clockwise with a steady firm pressure until the reamer has been turned all the way through the hole. When reaming steel, use cutting oil or machine oil to lubricate the tool. When reaming soft iron, do not lubricate the tool. To remove the reamer from the hole turn the wrench clockwise and raise the reamer simultaneously.

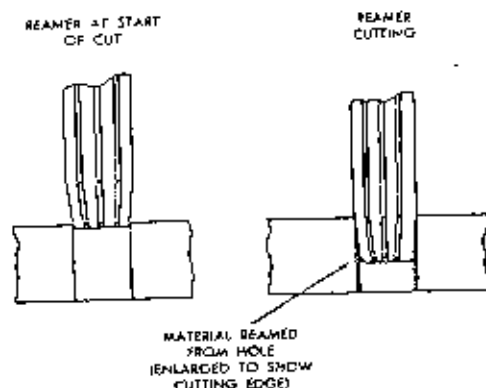


Figure 2-6-49.—Reaming a hole with a straight hole reamer.

NOTE: Turning the wrench too fast or too slowly will cause the reamer to chatter, producing an unevenly reamed hole.

INSTALLING A TAPER PIN

To install a tapered pin, refer to the blueprint or drawing for the proper size of pin to use. The size will be given as a number and length in inches (see the table in figure 2-6-50.) For instance, a No. 3 pin 1 3/4" long might be specified. Then, when you have the proper pin, measure the diameter of its small end and drill a hole of that size through for, example, the hub of a flange and a shaft while the flange is in place on the shaft. (See fig. 2-6-51.) Then select the same number of tapered pin reamer, a No. 3 in this case.

No. of Pin	DIAMETER AT LARGE END		MAX. LENGTH
	D	D	
00000	0.094	3/32	1/8
0000	.108	1/8	1/8
000	.123	1/4	1
00	.141	3/16	1 1/8
0	.156	1/2	1 1/4
1	.172	5/16	1 1/2
2	.190	3/4	1 3/4
3	.219	7/8	1 7/8
4	.250	1	2
5	.299	1 1/8	2 1/4
6	.341	1 1/4	3
7	.403	1 1/2	3 1/4
8	.492	1 3/4	4 1/2
9	.591	1 7/8	5 1/4
10	.706	2	6
11	.860	2 1/4	7 1/4
12	1.032	2 1/2	8
13	1.241	2 3/4	11
14	1.525	3	13

Figure 2-6-50.—Chart for Standard taper pins.

Figure 2-6-52 shows specifications of various sizes of reamers. The specifications given opposite the reamer numbers in the left-hand column of the table in figure 2-6-52 are the dimensions of the reamers. The small end of the reamer should just enter the hole you drill and, if the proper size of reamer has been selected, the pin will fit exactly. Turn the tapered pin reamer with a tap wrench

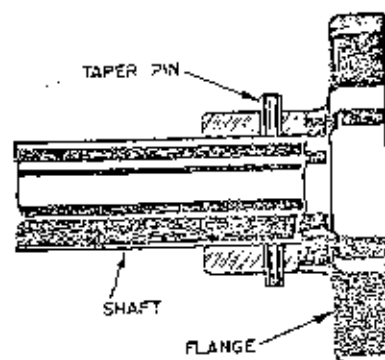


Figure 2-6-51.—A tapered pin installed in a shaft and flange.

No. of Taper Pin Reamer	Diameter at Large End of Reamer	Diameter at Small End of Reamer	Length of Flute
7/0	0.0666	0.0197	13/16
6/0	0.0806	0.0611	15/16
5/0	0.0966	0.0719	1 3/16
4/0	0.1142	0.0869	1 5/16
3/0	0.1302	0.1029	1 5/8
2/0	0.1462	0.1137	1 9/16
0	0.1638	0.1287	1 11/16
1	0.1798	0.1447	1 11/8
2	0.2008	0.1605	1 15/16
3	0.2294	0.1813	2 5/16
4	0.2604	0.2071	2 9/16
5	0.2994	0.2409	2 13/16
6	0.3540	0.2773	3 1/16
7	0.4220	0.3297	4 7/16
8	0.5050	0.3971	5 3/16
9	0.6066	0.4805	6 1/16
10	0.7216	0.5799	6 13/16

Figure 2-6-52.—Chart for diameters and length of taper reamers.

slowly and in a clockwise direction only, lifting it out of the hole to clean away the chips while it is still turning. If you reverse the direction of the reamer, chips may be wedged behind its cutting edges, causing them to break. Ream brass dry but apply cutting oil liberally when reaming steel. Try the taper pin in the hole several times as the reaming progresses. Stop reaming when the pin protrudes the same amount on both sides of the hub of the gear. REMOVING BURRS WITH A PIPE REAMER

After a piece of pipe has been cut, the ends should be reamed to remove the burr that is left on the inside of the pipe. This burr, if not removed, will restrict the flow of fluid in the pipe. Besides the reamer to trim the burr inside the pipe you will need a vise to hold the pipe steady. After making sure the pipe is held firmly in the vise, insert the reamer in the end of the pipe and turn the handle. (See fig. 2-6-53.) Rotate the handle of the reamer

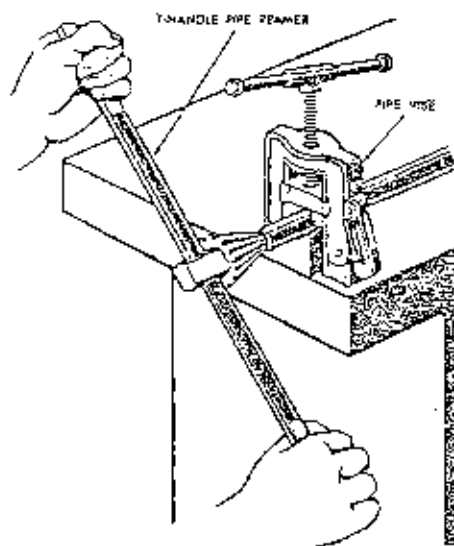


Figure 2-6-53.—Using a pipe reamer to remove burrs from pipe.

clockwise in short even strokes until the burrs inside the cut piece of pipe are completely removed. Remove the reamer from the pipe by rotating it clockwise.

CUTTING PIPE AND TUBING

Pipe cutters are used to cut pipe made of steel, brass, copper, wrought iron, and lead. Tube cutters are used to cut tubing made of iron, steel, brass, copper, and aluminum. The essential difference is that tubing has considerably thinner walls than piping. A cold chisel and hammer are used to cut pipe that is made from cast iron. If a pipe or tubing cutter is not available, a hacksaw may be used to cut either pipe or tubing.

CUTTING IRON PIPE TO LENGTH WITH A PIPE CUTTER

Before you cut pipe, make certain the required correct length is determined. There are three methods of measuring threaded pipe, and you must understand these methods if the pipe is to be cut to the correct length. (See fig. 2-6-54.)

The end-to-end method includes measuring the threaded portions of the pipe and measuring the pipe from end to end. The end-to-center method is used on a section of pipe that has a fitting screwed on one end only; measure from the free end of the pipe to the center of the fitting at the other end of the pipe. The center-to-center method is used when both ends of the pipe have fittings; measure from the center of one fitting to the center of the other fitting at the opposite end of the pipe.

The approximate length of thread on 1/2- and 3/4-inch wrought iron or steel pipe is 3/4 inch. On 1-, 1 1/4-, and 1 1/2-inch pipe, it is approximately 1 inch long. On 2- and 2 1/2-inch pipe, the length of thread is 1 1/8 and 1 1/3 inches respectively.

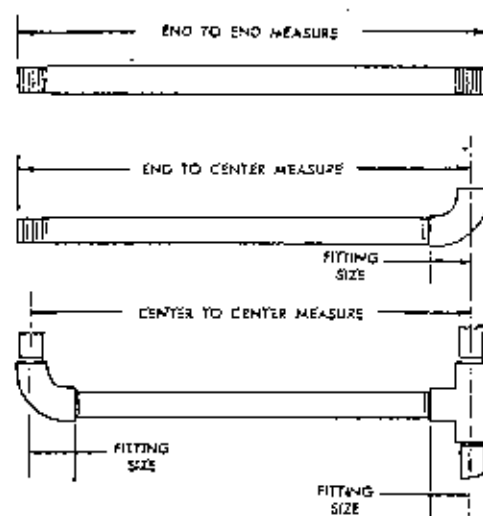


Figure 2-6-54.—Proper methods for measuring pipe to desired lengths.

To determine the length of pipe required, take the measurement of installation such as center to center of the pipe requiring two fittings. Measure the size of the fittings as shown in figure 2-6-54. Subtract the total size of the two fittings from the installation measurement. Multiply the approximate thread length by 2 and add the result to the length obtained. This will give the length of pipe required.

After the length of the pipe has been determined, measure the pipe and mark the spot where the cut is to be made with a scriber or crayon. Lock the pipe securely in a pipe vise.

Inspect the cutter to make sure that there are no nicks or burrs in the cutting wheel. Open the jaws of the cutter by turning the handle counterclockwise. Position the cutter around the pipe at the marked point. Make sure the cutting wheel is exactly on the mark and close the jaws of the cutter lightly against the pipe by turning the cutter handle clockwise. After making contact, turn the cutter handle clockwise one-fourth of a turn more. This will put a bite on the pipe.

Grasp the cutter handle and rotate the cutter as a whole one complete revolution, swinging it around the pipe in the direction indicated in figure 2-6-55. Turn the cutter handle clockwise

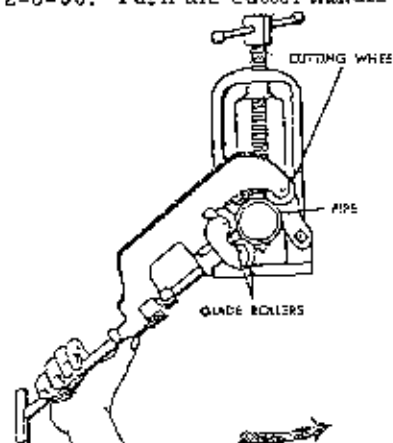


Figure 2-6-55.—Cutting pipe with a pipe cutter.

one-fourth of a turn more to take another bite on the pipe and rotate the cutter another complete revolution. Keep the cutter perpendicular to the pipe at all times or the wheel will not track properly. Repeat this operation until the pipe is cut. Remove the small shoulder on the outside of the pipe with a file and remove the burr on the inside with a reamer.

CUTTING METALLIC TUBING WITH A TUBE CUTTER

Copper tubing is one of the most generally used kinds of metallic tubing readily cut with a tube cutter. This cutter works the same as a pipe cutter but is smaller. To cut tubing, place the tube cutter with the cutting wheel on the mark where the cut is to be made. Move the cutting wheel into light contact with the tubing. See step 1 in figure 2-6-56. Then swing the handle around the tubing as you feed



STEP ①
SCREW THE CUTTING WHEEL
LIGHTLY AGAINST THE TUBING



STEP ②
ROTATE THE CUTTER KEEPING A SLIGHT
PRESSURE AGAINST THE CUTTING WHEEL
WITH THE SCREW ADJUSTMENT.

Figure 2-6-56.—Steps in cutting tubing with a tube cutter.

the cutting wheel a little for each revolution by turning the screw adjustment. Different wall thicknesses, kinds, and diameters of metallic tubing require different feeds. Step 2, figure 2-6-56 indicates the direction of rotation. The feed pressure is correct when it keeps the wheel cutting but does not flatten the tubing.

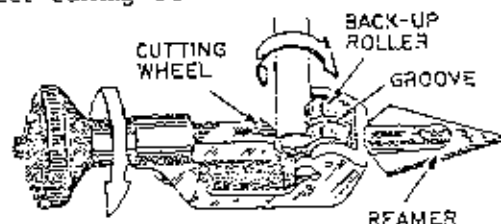


Figure 2-6-57.—Cutting tubing close to the base of a flare.

The design of some tubing cutters will permit cutting off a flared end close to the base of the flare. In figure 2-6-57, notice the groove in the backup roller. Place the flare in this groove so that the cutting wheel rides at the base of the flare. Then cut off the flare as you would cut tubing.

Burrs that form may be similar to those formed when cutting pipe. Remove the inside burr with the reamer attached to the tubing cutter opposite the handle. See figure 2-6-58.



Figure 2-6-58.—Reaming the burrs from a piece of tubing.

In some cases a three-cornered scraper, pocketknife blade, or round file may work better than the reamer. After reaming clean out the chips. Then remove any outside burr with a mill file.

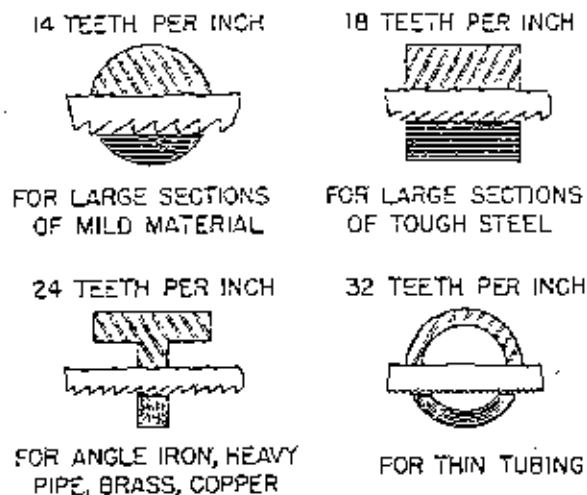
USING HACKSAWS

Hacksaws are among the most useful tools for cutting metal. They may be either hand-operated or powered by electricity. The power hacksaw is a great time-and-labor saver in a shop where much metalwork is done. It will cut much faster and more accurately than can usually be done by hand. When cutting heavy bars, the power hacksaw can be started and allowed to run by itself while other work is being done in the shop.

Like the file, however, the hacksaw is often used improperly. Although it can be used with limited success by an inexperienced man, a little thought and study given to its proper use will result in faster and better work and less dulling and breaking of blades.

Good work with a hacksaw depends not only upon the proper use of the saw, but also upon the proper selection of the blades for the work to be done. Figure 2-6-59 will help you select the proper blade to use when sawing metal with a hacksaw. Coarse blades with fewer teeth per inch cut faster and are less liable to choke up with chips. However, finer blades with more teeth per inch are necessary when thin sections are being cut. The selection should be made so that, as each tooth starts its cut, the tooth ahead of it will still be cutting.

To make the cut, first install the blade in the hacksaw frame (fig. 2-6-60) so that the teeth point away from the handle of the hacksaw. Hand hacksaws cut on the push stroke, whereas power hacksaws cut on the pull stroke. Tighten the wingnut so that the blade is definitely under tension. This helps make straight cuts.



KEEP AT LEAST TWO TEETH CUTTING
TO AVOID THIS



Figure 2-6-59.—Selecting the proper hacksaw blade.

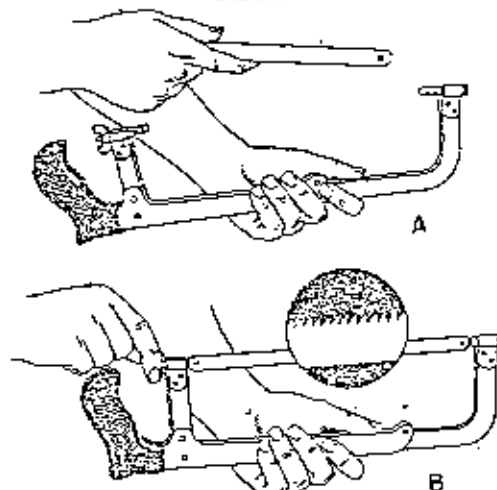


Figure 2-6-60.—Installing a hacksaw blade.

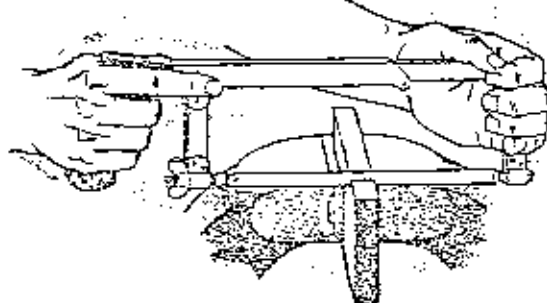


Figure 2-6-61.—Proper way to hold a hacksaw.

Hold the job in a vise with a minimum of overhang. This will reduce vibration, give a better cut, and lengthen the life of the blade. Have the layout line outside of the vise jaw so that the line is visible while you work. The index finger of the right hand, pointed forward, aids in guiding the frame. (See fig. 2-6-61.)

A stroke is one forward-and-back movement of the hacksaw frame. Let your body sway ahead and back with each stroke. Apply pressure on the forward stroke, which is the cutting stroke, but not on the return stroke. From 40 to 50 strokes per minute is the usual speed. Long, slow, steady strokes are much preferred.

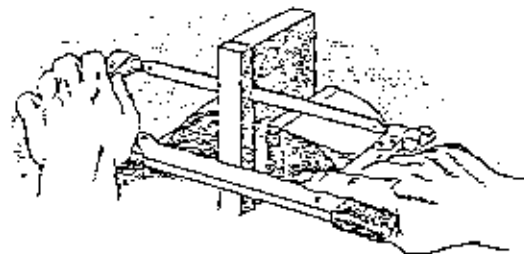


Figure 2-6-62.—Making a long cut near the edge of stock.

For long cuts (fig. 2-6-62) rotate the blade in the frame so that the length of the cut is not limited by the depth of the frame. Hold the work with the layout line close to the vise jaws, raising the work in the vise as the sawing proceeds.

Saw thin metal as shown in figure 2-6-63. Notice the long angle at which the blade enters the saw kerf. This permits several teeth to be cutting at the same time.

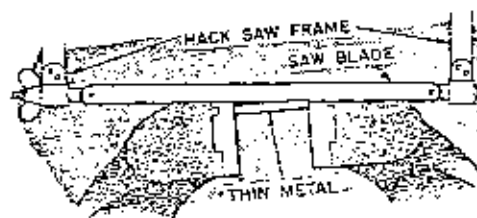


Figure 2-6-63.—Cutting thin metal with a hacksaw.

Metal which is too thin to be held, as shown in figure 2-6-63, can be held between blocks of wood, as shown in figure 2-6-64. As shown in figure 2-6-64A, the wood provides support for several teeth as they are cutting. Without the wood, as shown at B in figure 2-6-64, teeth will be broken due to excessive vibration of the stock and because individual teeth have to absorb the full power of the stroke.

Cut thin metal with layout lines on the face by using a piece of wood behind it. (See fig.

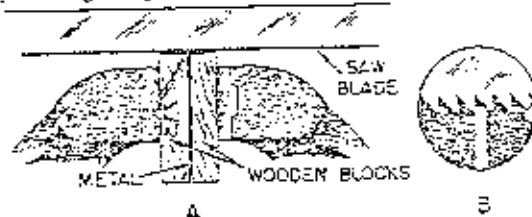


Figure 2-6-64.—Cutting thin metal between two wooden blocks.

2-6-65.) Hold the wood and the metal in the jaws of the vise, using a C-clamp in addition when necessary. The wood block helps support the blade and produces a smoother cut. Using the wood only in back of the metal permits the layout lines to be seen.

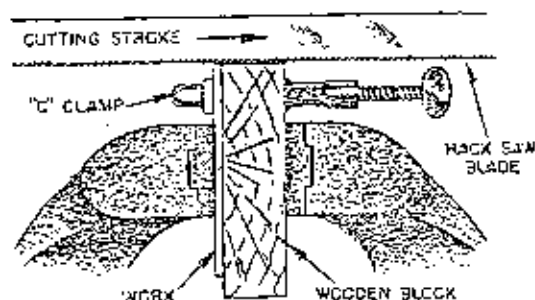


Figure 2-6-65.—Cutting thin metal using wood block with layout lines.

To remove a frozen nut with a hacksaw, saw into the nut as shown in figure 2-6-66, starting the blade close to the threads on the bolt or stud and parallel to one face of the nut as shown in figure 2-6-66A. Saw parallel to the bolt until the teeth of the blade almost reach the lockwasher. Lockwashers are hard and will ruin hacksaw blades, so do not try to saw them. Figure 2-6-66B shows when to stop sawing. Then, with a cold chisel and hammer, remove this one side of the nut completely by opening the saw kerf. Put an adjustable wrench across this new flat and the one opposite, and again try to remove the frozen nut. As very little original metal remains on this one side of the nut, the nut will either give or break away entirely and permit its removal.

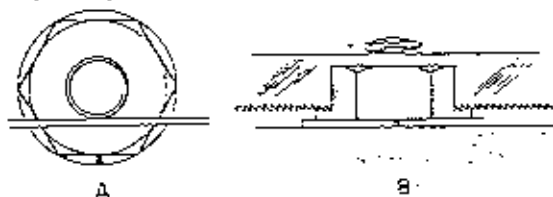


Figure 2-6-66.—Removing a frozen nut with a hacksaw.

To saw a wide kerf in the head of a cap screw or machine bolt, fit the hand hacksaw frame with two blades side by side, and with teeth lined up in the same direction. With slow, steady strokes, saw the slot approximately one-third the thickness of the head of the cap screw as shown in figure 2-6-67. Such a slot will permit subsequent holding or turning with a screwdriver when it is impossible, due to close quarters, to use a wrench.

Most power hacksaws found in small shops will make a square cut in stock up to 4 by 4

inches and take a standard 12-in. power hacksaw blade. This size saw is generally operated by a 1/3 horsepower electric motor. Power hacksaws cut on the pull stroke and automatically release the pressure on the backstroke. The pressure applied on the cutting stroke is adjustable.

As with hand hacksaws the blades should be selected according to the kind of sawing to be done. Blades with 18 teeth per inch are recommended for cutting thin sections like angle iron, pipe, and tubing, and are generally quite satisfactory for general work in the shop. Coarser toothed blades with 14, or even 10 teeth per inch, may be used for faster cutting in heavy stock.

Some of the main points to remember when operating a power hacksaw are:

1. Always clamp the work securely in the saw vise.
2. Before starting the saw, be sure the blade is up and out of contact with the work. After the blade is in motion, let it down gently onto the work, holding up on the handle slightly to reduce the pressure while the blade is starting to cut.
3. Always keep the blade tight in the saw frame.
4. Use a suitable cutting pressure on the blade, just enough to keep it cutting well.
5. Clamp the work so that the blade will not have to cut straight across thin sections.
6. Be sure to insert the blades so that the teeth will point in the direction of cutting.
7. Clamp the angle irons with the ridge up. Two or more may be cut at the same time by nesting them.
8. Do not push down on the saw to add pressure to the blade. The teeth can cut only as fast as their size will permit.
9. Run the saw at the speed recommended by the manufacturer.

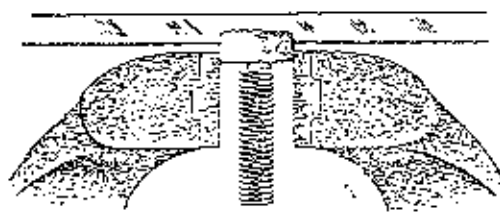


Figure 2-6-67.—Cutting a wide kerf in the head of a cap screw or bolt.

MISCELLANEOUS SKILLS

A number of miscellaneous skills that are common cannot be properly categorized in any of the foregoing sections. For example, skills introduced in this section may require the use of tools that are not used in such operations as cutting, grinding, measuring, etc. To accomplish some of these skills, a combination of particular materials, tools, and work methods is needed.

GLASSCUTTING

Two glasscutters are generally available for use.

One is the single wheel, general purpose type (fig. 2-7-1), while the other is a 2-to 24-inch circular capacity type incorporating a graduated beam (not illustrated).

A glasscutter actually does not cut glass; it splits it. If the wheel is sharp and it is drawn over the glass at the right speed and pressure, it makes a fine score or groove by slightly crushing or pulverizing the glass under the edge of the wheel. The beveled sides of the wheel act as wedges which push against the sides of the groove and pry the glass apart so that a crack is started. If a crack fails to start in the cutting, tap the scratch or score with the ball end of the glasscutter to start a crack.

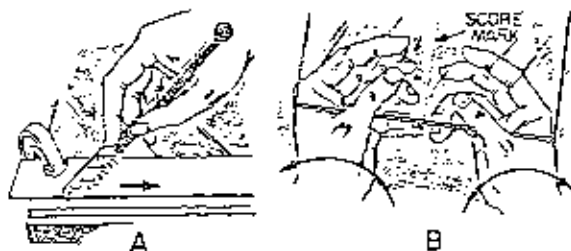


Figure 2-7-1.—Using a glasscutter.

Before trying to make a finish cut in a piece of glass, get a scrap piece and make several cuts on it. This helps you discover the proper speed and pressure that are required to get a smooth edge.

Ordinary window glass comes in two thicknesses, single light and double light. Single light is thinner and easier to cut. Plate glass up to 1/4 inch in thickness can be cut in the same manner as ordinary window glass. Safety glass, which consists of two or more glass sheets cemented together by a transparent plastic, requires special cutting equipment.

MAKING STRAIGHT CUTS IN ORDINARY GLASS

To make straight cuts in glass, follow the steps shown in figure 2-7-1. In scoring the glass, hold the glasscutter as you would a pencil. Draw the glasscutter toward you over the surface of the glass.

To break a small piece of glass, grasp the piece in both hands with the score mark up. Then push upward with your fingers beneath the score mark, and downward with your thumbs. The glass will break almost instantaneously along the entire score mark.

Straight cuts can also be made with the use of a straightedge. The straightedge must be held firmly in place, however. Figure 2-7-2 shows a straightedge held in place with a pair of C clamps. Other means of holding the straightedge in place are also acceptable. In placing the straightedge, make allowance for

the fact that the wheel of the glasscutter must pass through the centers of the locating marks. Therefore, the score mark when made will be a slight distance from the straightedge itself.

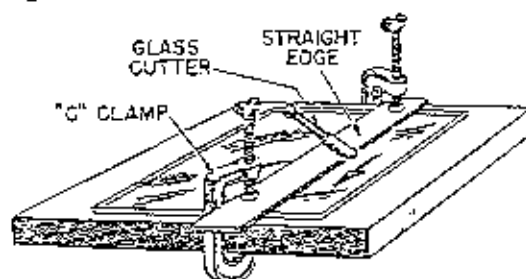


Figure 2-7-2.—Using a straightedge when cutting glass.

Dip the end of the glasscutter in kerosene before drawing it across the surface of the glass. Apply only light or medium pressure for glass that is about 1/8-inch thick. Too much pressure will tend to chip the glass along both sides of the score mark. The score mark should be only one barely visible line on the surface of the glass extending the entire distance from edge to edge. Make it in one pass. To go over it a second time may cause an uneven break.

For breaking large sheets of glass by scoring, lay the glass as shown in figure 2-7-3A, with the score mark on the top surface. Then tap the bottom surface just under the score mark, using the handle of the glasscutter. This will "start" the break at that point although the start may not be visible.

Then lay a piece of chalk line, or similar cord, on the bench top to raise the glass slightly, and place the score mark right over it. (See fig. 2-7-3B.) (In all glass work, the score mark is kept on the top face of the work.) Carefully apply downward pressure at points B and C, figure 2-7-3B, on both sides of the score mark. The crack that you started by tapping beneath one end of the score mark from the bottom surface of the glass will then almost instantly follow the score mark across the width of the sheet leaving the two pieces of glass in

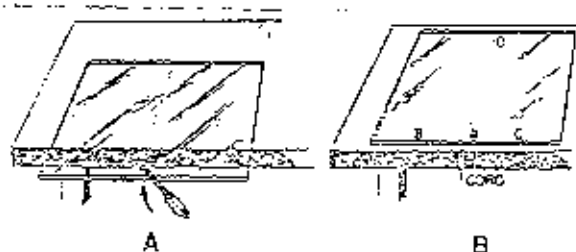


Figure 2-7-3.—Cutting large sheets of glass. the clear. When pressure at points B and C starts the crack on its way from A to D, but the crack does not reach D, then apply pressure progressively toward D, but always slightly behind the point to which the crack has run. For short breaks, a matchstick can be substituted for the cord.

Figure 2-7-4 shows a break that did not follow the score mark. When this happens, grasp the remaining piece with glass pliers right up to the score mark and carefully apply pressure downward away from the score mark. A glass pliers is a broad-nosed pliers. If you do not have glass pliers, use ordinary pliers. It may be necessary to "nibble" off whatever scrap glass remains if the first break fails to follow the entire width of the glass.

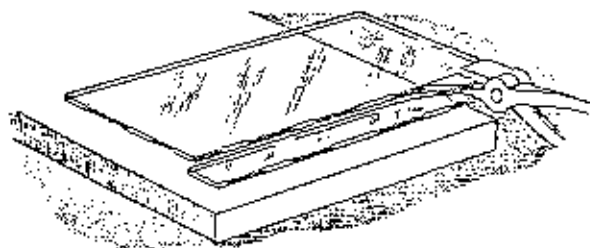


Figure 2-7-4.—Using pliers to aid in separating glass.

CUTTING GLASS TO A PATTERN

To cut glass to a pattern, first lay out a full size drawing on paper, making certain the outline is heavy and distinct. Place the drawing under the pane of glass to be cut. Cut circles, ovals, and curves by tracing them through the glass with the cutter wheel. For straight lines, use a guide such as a woodstrip or a yardstick.

CUTTING LAMINATED SAFETY GLASS

To cut laminated safety glass, make the score mark just as you would for ordinary glass and open or snap the cut on one side. Then turn the sheet of glass over on the bench top and make another score mark exactly opposite the first one, and open this score mark separately just as you would for un laminated glass. Use a cord or matchstick to assist in breaking the glass if necessary.

When both glass faces of the laminated safety glass have been scored and cut or snapped, secure the glass to the bench top as shown in figure 2-7-5. Then pull horizontally with glass pliers or common pliers, with pads of rubber to protect the surface of the glass from the jaws. When the cut is opened up in this way, cut the layer of plastic with a razor blade as shown. Pulling horizontally prevents chipping the edges of the glass on the bottom side which is what would happen if the top of the cut were opened up by bearing down on the pliers rather than pulling horizontally.

For satisfactory cutting, laminated safety glass must be at a temperature of between 75° and 110° F. However, to facilitate stretching the plastic so that it can be cut with a razor blade, it may be necessary to raise the temperature above this. After the glass has been

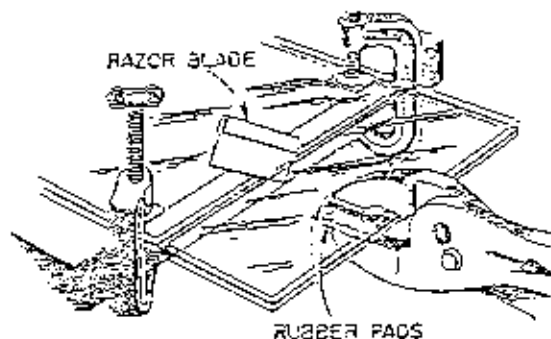


Figure 2-7-5.—Cutting laminated safety glass, scored and snapped, heat the plastic by immersing the whole sheet of glass in hot water (160° to 170° F) for a short period not to exceed a minute. Cut the plastic membrane clear through immediately upon removing the glass from the hot water. Then wipe the plate dry and stand it on its edge until it has cooled to almost room temperature. Do not attempt to hurry the cooling with a fan or other means.

CUTTING GLASS TUBING

One way to cut glass tubing, as shown in figure 2-7-6, is to score the surface with one forward stroke of a three-cornered file. The corner of a mill file will also work well in the absence of a three-cornered file. Make the score mark at right angles to the center line of

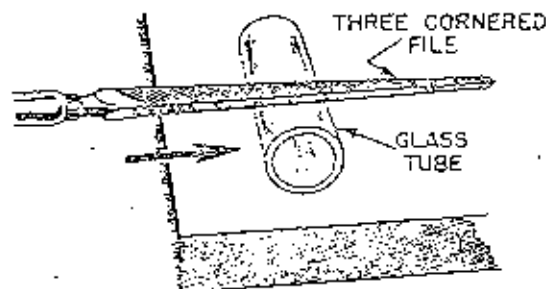


Figure 2-7-6.—Cutting glass tubing with a three-cornered file.

the tube so that the tube will snap squarely across. To snap the tube, place it on the bench top with a matchstick or toothpick directly beneath the score mark. Then, holding one end securely, press down on the other end and the snap will be immediate.

If possible, cut glass tubing with the gage glasscutter shown in figure 2-7-7. Set the stop collar to permit the cutting wheel to be inserted the required distance into the end of the tubing to make the cut where you want it. The backup shoe will ride on the outside surface of the tube exactly opposite the cutting wheel. If the glass is pyrex glass, it may be necessary to use a new, sharp cutting wheel for each gage glass that is to be cut, because pyrex glass is extremely hard. Apply pressure on the handles of the gage glasscutter with one hand and rotate the glass with the other. The score mark will be on the inside of the tube.

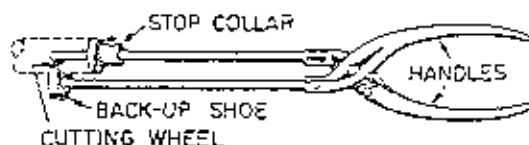


Figure 2-7-7.—Using a gage glasscutter for cutting glass tubing.

To break the glass tubing at the score mark, hold the glass in both hands with your thumbs at the mark. (See fig. 2-7-8.) Then pull against your thumb pressure and away from the score mark. On some glass tubing this method may be more satisfactory than using a matchstick.

To remove the sharp corners at the fresh cut, hold the glass at the edge of the bench as shown in figure 2-7-9, then, with a piece of

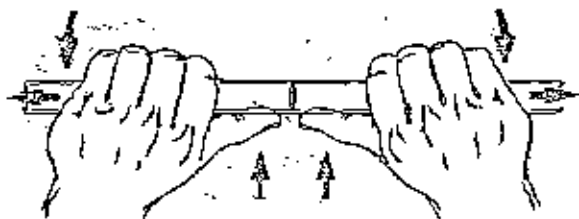


Figure 2-7-8.—Breaking glass tubing at the scored mark.

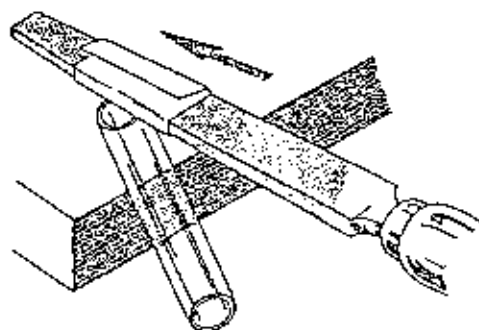


Figure 2-7-9.—Smoothing the cut edge of glass tubing.

emery cloth wrapped around a file, work your way around the entire circumference of the tube with forward strokes.

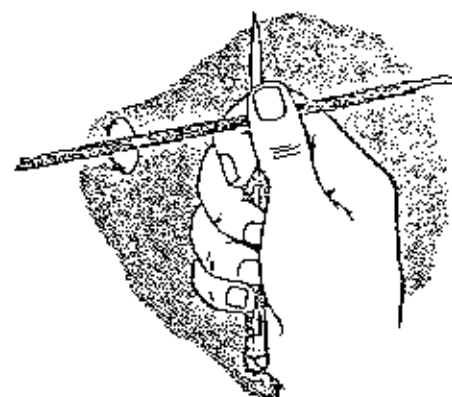
STRIPPING INSULATED WIRE

Insulation may be stripped from wire by using one of several tools. However, a pocketknife or side cutting pliers are generally used for this work.

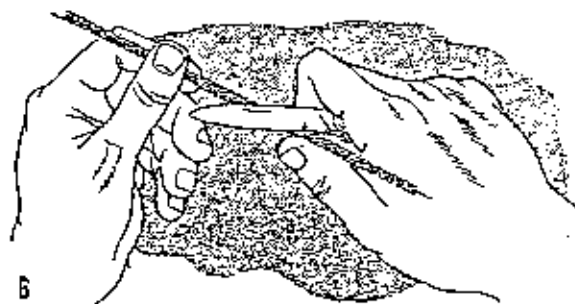
When using a pocketknife for stripping insulation, hold the wire in one hand and the knife in the other. Use your thumb to roll the wire over the blade of the knife to cut the insulation almost to the wire itself. (See figure 2-7-10A.) Then pull off or "strip" the short piece of insulation from the end of the wire. Because any nick in the wire will eventually cause a break, it is

important not to cut clear through the insulation. By not cutting completely through the insulation, the blade of the knife never comes into contact with the wire itself, thus preventing any possible injury to the surface of the wire. However, cutting nearly through the insulation weakens it sufficiently so that the insulation can be stripped from the wire. This method is not recommended for stranded wire.

Another way to perform this operation is, while holding the wire in one hand and the pocketknife in the other, hold the wire against the knife blade with your thumb and cut the insulation off with several strokes of the blade, working around the wire with each successive stroke. (See fig. 2-7-10B.) Notice that the blade is held almost flat against the insulation. This low angle prevents the blade from cutting into the wire itself. This method is not recommended for stranded wire.



A



B

Figure 2-7-10.—Stripping insulated wire with a pocket knife.

Insulated wire can be stripped with the side cutting pliers, as shown in figure 2-7-11, by nicking the insulation all around, being careful not to break through to the wire itself, and stripping the short length of insulation off the end of the wire. Notice that, in figure 2-7-11A, the man's index finger is wedged between the handles of the pliers close to the joint. This affords better control over the cutting edges so that there is less chance that the insulation will be broken completely through. When the nick has been made all around the wire, press your thumb against the side of the pliers to break the insulation at the nick and, without changing the grip of

the pliers, strip it off the end. (See fig. 2-7-11B.) Care must be exercised to avoid cutting too far through the insulation and nicking the wire.

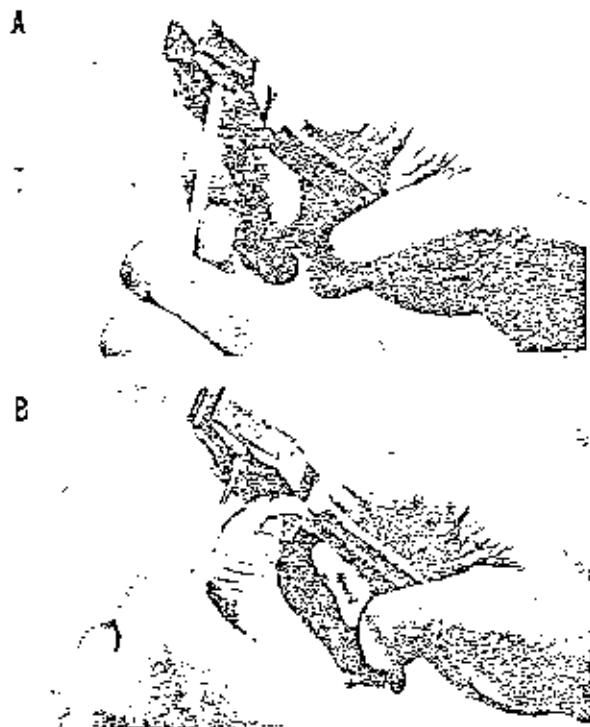


Figure 2-7-11.—Stripping insulated wire with side cutting pliers.

Insulated solid wire can also be stripped as shown in figure 2-7-12. Starting at the end of the wire, grip and crush the insulation between the flat places on the inside of the handles close to the hinged joint. In figure 2-7-12A, the insulation has been crushed and the wire exposed. Then, as shown in figure 2-7-12B, grasp the insulation close to the end of the crushed portion and tear it off. Although this method leaves a rather ragged appearing end on the remaining insulation, there is no possibility of damaging the wire.

BENDING AND FLARING METALLIC TUBING

External spring-type benders, shown in figure 2-7-13A, come in sizes to bend $1/4"$, $5/16"$, $3/8"$, $7/16"$, $1/2"$, and $5/8"$ outside-diameter soft copper, aluminum, and other soft metallic tubing. To bend tubing with this type of bender, first select the size that will just slip over the size of tubing you want to bend. Then slip it over the tubing so that it centers at the middle of the proposed bend. Grasp the bender with both hands and make the bend. (See fig. 2-7-13B.) The restraining action of the bender will prevent the tubing from collapsing at the bend and will produce a smooth curve. To remove the bender, grasp the beveled end and pull it off the tubing.

Internal spring-type benders, shown in figure 2-7-13C, come in sizes to bend $3/8"$, $1/2"$, and $5/8"$ outside diameter tubing. This type can be used when both ends of a length of tubing are

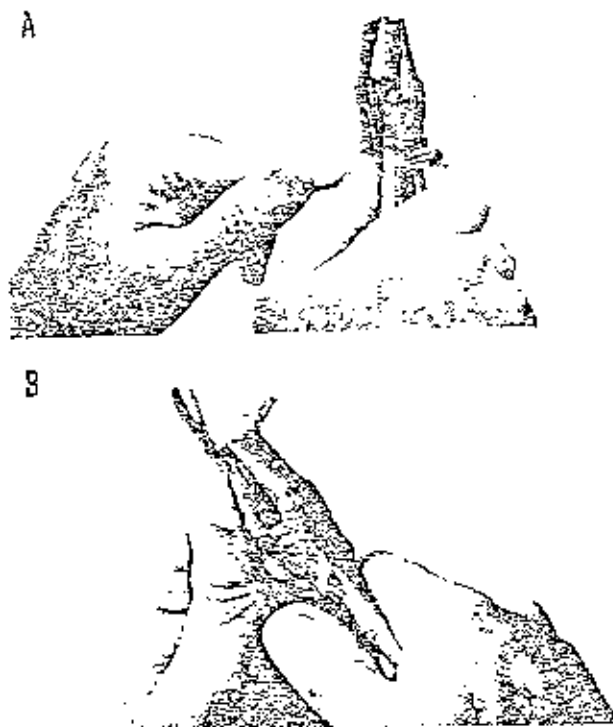


Figure 2-7-12.—Stripping insulated wire with side cutting pliers.

flared and the external type cannot be applied. To bend tubing with an internal spring-type bender, select the proper size bender and slip it inside of the tubing. Insert it so that the center of its length is at the center of the proposed bend. Grasp the tubing with both hands and make the bend. If the bender sticks out of the end of the

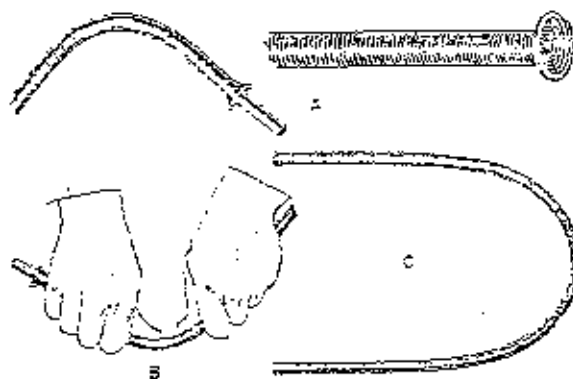


Figure 2-7-13.—Bending tubing with spring type tube benders.

tubing, remove it by pulling it out. If not, remove it with a fish wire or other simple means.

The bender shown in figure 2-7-14 is an open-side mandrel type. By open-side is meant that one side is open so that the bender can be placed on the tubing at any point along the length of the tubing. The mandrel is the circular portion of the bender around which the tubing is

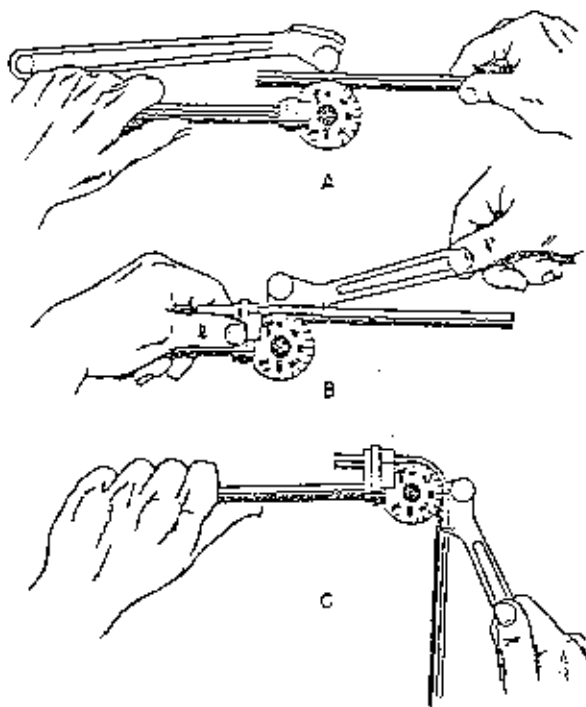


Figure 2-7-14.—Bending tubing with an open-side mandrel type bender.

formed or bent. This type of bender is furnished in 3/16", 1/4", 5/16", 3/8", and 1/2" sizes. Place the bender on the tubing at the point where the bend is required. Figure 2-7-14A, shows the zero line on the bender which indicates the start of the bend. Then close the bender, as shown in figure 2-7-14B, and by bringing your two hands toward each other, bend the tubing around the mandrel until the index line on the arm indicates the angle of the bend you require. Then open the bender, as shown in figure 2-7-14C and remove it from the tubing. For larger sizes of tubing similar mandrel-type benders are used. These are geared for greater mechanical advantage but their operation is basically the same.

Tube flaring is a method of forming the end of a copper tube into a funnel shape so that it can be held by a threaded fitting. A partially threaded flare nut is slipped over the tube, the end of the tube is flared, the flare is seated with the inside of the flare against the end of a fitting which has threads on the outside, and then the flare nut is screwed onto the fitting, pushing the outside of the flare against the seating surface of the fitting.

The tube-flaring tool shown in figure 2-7-15 is one type which is commonly used to flare copper tubing. To flare the end of tubing, first check to see that it has been cut off squarely and has the burrs removed from both inside and outside. Remember to slip the flare nut on the tube before you make the flare. Then, as shown in figure 2-7-15A, open the flaring tool at the die which corresponds to the size of the tubing being flared. Insert the end of the tubing to protrude slightly above the top face of the die blocks. The amount by which the tubing extends above the blocks determines the finished diameter of the flare. The flare must be large enough so

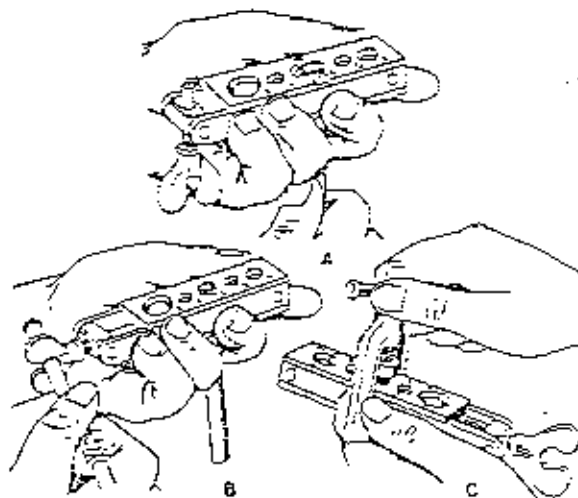


Figure 2-7-15.—Flaring metallic tubing.

that it will seat properly against the fitting, but small enough so that the threads of the flare nut will slide over it. You determine the correct size by trial-and-error. Then as shown in figure 2-7-15B, close the die block and secure the tool with the wing nut. Use the handle of the yoke to tighten the wingnut. Then place the yoke over the end of the tubing (fig. 2-7-15C), and tighten the handle to force the cone into the end of the tubing. The completed flare should be slightly visible above the face of the die blocks.

REMOVING BROKEN BOLTS AND STUDS

When the removal of a broken bolt or stud from work is required, use plenty of oil to flood the part being worked on. Penetrating oil is the most effective. Time permitting, soak the area for several hours or overnight. A week's soaking may loosen a bolt which would otherwise have to be drilled out.

If enough of the broken piece protrudes from the job, take hold of it with locking pliers, as shown in figure 2-7-16, and carefully try to ease it out. The smaller sizes of bolts are very liable to twist off. If the bolt cannot be turned, further soaking with penetrating oil may help. Or try removing the pliers and jarring the bolt with light hammer blows on the top and around the sides. This may loosen the threads so that the bolt can then be removed with the locking pliers.

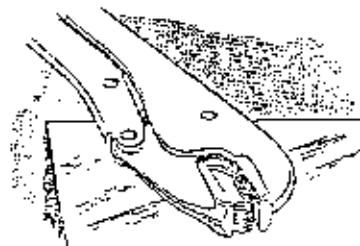


Figure 2-7-16.—Removing a broken stud with locking pliers.

If a bolt has been broken off flush with the surface of the job, as shown in figure 2-7-17, it is sometimes possible to back it out of the hole with light blows of a prick punch or center punch.

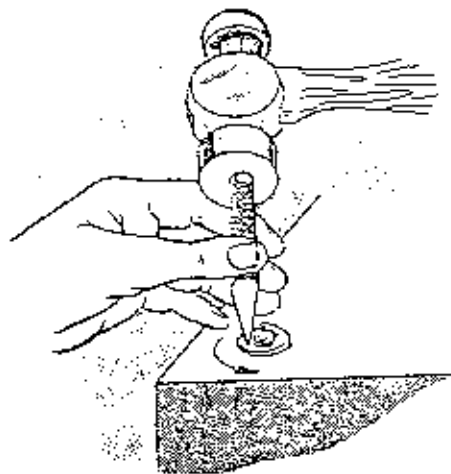


Figure 2-7-17.—Removing a broken bolt with a prick punch.

However, if the bolt was broken due to rusting, this method will not remove it. If it cannot be removed by careful punching first on one side and then the other, a screw and bolt extractor may remove it. (See fig. 2-7-18B.)

When using this extractor, file the broken portion of the bolt to provide a smooth surface at the center for a punch mark, if possible. Then carefully center punch the exact center of the bolt (See fig. 2-7-18A.)

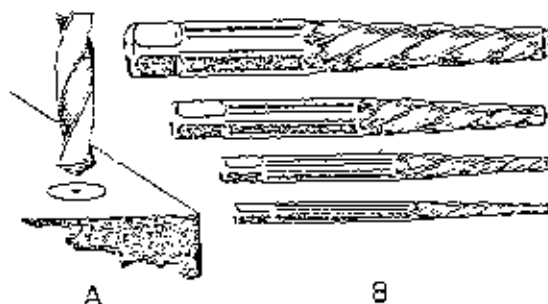


Figure 2-7-18.—Screw and bolt extractors for removing broken studs.

Refer to figure 2-7-19 to select the proper drill size to use according to the size of the broken bolt that you are trying to remove. If possible, drill through the entire length of the broken bolt. Then carefully work some penetrating oil through this hole so that it fills the cavity beneath the bolt and has a chance to work its way upwards from the bottom of the bolt. The more time you let the penetrating oil work from both ends of the broken bolt, the better are your chances of removing it.

When drilling a hole in a stud which has broken off below the surface of the piece which it was holding, as shown in figure 2-7-20A, a drill guide will center the drill and may be preferred rather than a center punch mark.

When the hole has been drilled, and additional penetrating oil has had time to soak, put the spiral end of the screw and bolt extractor into the hole. Set it firmly with a few light hammer blows and secure the tap wrench as shown at B in figure 2-7-20. Carefully try to back the broken bolt out of the hole. Turn the extractor counterclockwise. This type of extractor is designed for right hand threads only.

A screw and bolt extractor can sometimes be used to remove a socket-head capscrew, also called an Allen head capscrew, when the socket has been stripped by the Allen wrench. (See fig. 2-7-21.) When attempting this removal, carefully grind off the end of the extractor so that it will not bottom before the spiral has had a chance to take hold. Figure 2-7-21B shows this end clearance. In doing this grinding operation, great care must be taken to keep the temperature of the extractor low enough so that the tip can be handled with the bare hands. If the hardness is drawn from the tip of the extractor by overheating during the grinding, the extractor will not take hold.

REMOVING A BROKEN BOLT AND RETAPPING HOLE

To remove a broken bolt and retap the hole, file the bolt smooth, if necessary, and center-punch it for drilling.

Then select a twist drill which is a little less than the tap-drill size for the particular bolt that has been broken. As shown in figure 2-7-22, this drill will just about but not quite touch the crests of the threads in the threaded hole or the roots of the threads on the threaded bolt. Carefully start drilling at the center punch mark, crowding the drill one way or the other as necessary so that the hole will be drilled in the exact center of the bolt. The drill in figure 2-7-22 has almost drilled the remaining part of the bolt away and will eventually break through the bottom of the bolt. When this happens, all that will remain of the bolt will be a threaded shell. With a prick punch or other suitable tool, chip out and remove the first 2 or 3 threads, if possible, at the top of the shell. Then carefully start a tapered tap into these several clean threads and continue tapping until the shell has been cut away and the original threads restored.

In cases where the identical size of capscrew or bolt is not necessary as a replacement, center-punch and drill out the old bolt with a drill larger than the broken bolt, as shown in figure 2-7-23A. Tap the hole first, and then finish it with a bottoming tap as shown in figure 2-7-23B. Replace with a larger size capscrew or stud.

REMOVING A BROKEN TAP FROM A HOLE

To remove a broken tap from a hole, generously apply penetrating oil to the tap, working it down through the four flutes into the hole. Then, if possible, grasp the tap across the flats with

Size No.	Extractor Overall Length, Inches	Used For—		Use Drill Size Dia., Inches
		Nominal Screw And Bolt Size, Inches	Nominal Pipe Size, Inches	
1	2	3/16 - 1/4	-----	5/64
2	2 3/8	1/4 - 5/16	-----	7/64
3	2 11/16	5/16 - 7/16	-----	5/32
4	3	7/16 - 9/16	-----	1/4
5	3 3/8	9/16 - 3/4	1/4	17/64
6	3 3/4	3/4 - 1	3/8	13/32
7	4 1/8	1 - 1 3/8	1/2	17/32
8	4 3/8	1 3/8 - 1 3/4	3/4	13/16
9	4 5/8	1 3/4 - 2 1/8	1	1 1/16
10	5	2 1/8 - 2 1/2	1 1/4	1 5/16
11	5 5/8	2 1/2 - 3	1 1/2	1 9/16
12	6 1/4	3 - 3 1/2	2	1 15/16

Figure 2-7-19.—Chart for screw and bolt extractor.

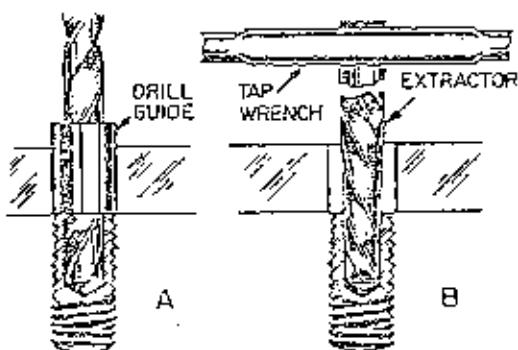


Figure 2-7-20.—Removing a stud broken off below the surface.

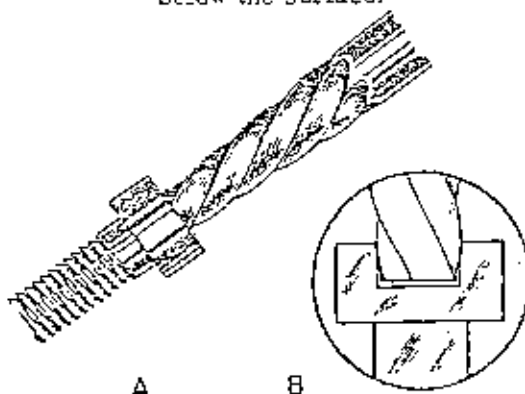


Figure 2-7-21.—Removing an Allen head cap-screw with a bolt extractor.

locking-type pliers. This operation is shown in figure 2-7-24. Carefully ease the tap out of the hole, adding penetrating oil as necessary.

If the tap has broken off at the surface of the work, or slightly below the surface of the work, the tap extractor shown in figure 2-7-25 may remove it. Again, apply a liberal amount of penetrating oil to the broken tap. Place the tap extractor over the broken tap and lower the upper collar to insert the four sliding prongs down

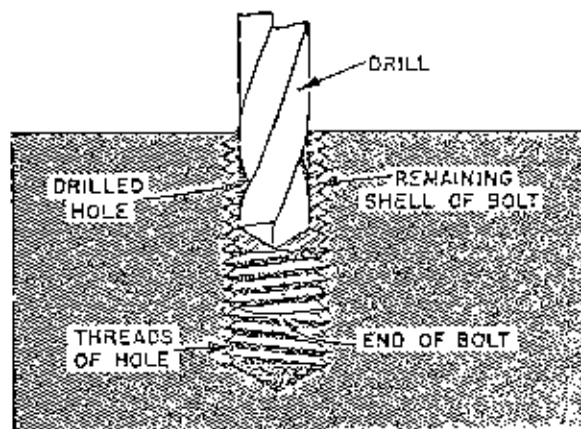


Figure 2-7-22.—Removing a broken bolt and retapping hole to same size.

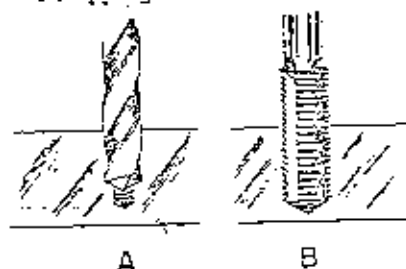


Figure 2-7-23.—Removing broken bolt and retapping hole to larger size.

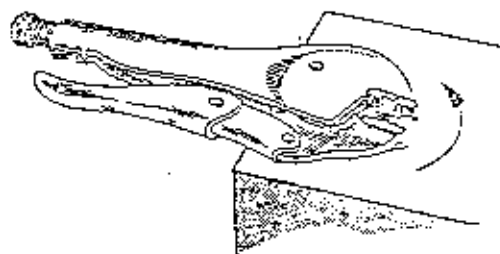


Figure 2-7-24.—Removing a broken tap with locking pliers.

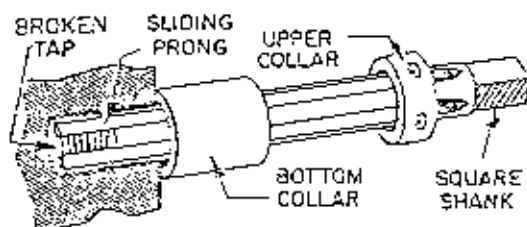


Figure 2-7-25.—Removing a broken tap with a tap extractor.

into the four flutes of the tap. Then slide the bottom collar down to the surface of the work so that it will hold the prongs tightly against the body of the extractor. Tighten the tap wrench on the square shank of the extractor and carefully work the extractor back and forth to loosen the tap. It may be necessary to remove the extractor and strike a few sharp blows with a small hammer and pin punch to jar the tap loose. Then reinsert the tap remover and carefully try to back the tap out of the hole.

Each size of tap will require its own size of tap extractor. Tap extractors come in the following sizes: $1/4"$, $5/16"$, $3/8"$, $7/16"$, $1/2"$, $9/16"$, $5/8"$, $3/4"$, $7/8"$, and $1"$.

When a tap extractor will not remove a broken tap, it is often possible to do so by placing a hex nut over the tap (fig. 2-7-26), and plug welding the nut to the tap with an arc welder. Notice that the hole in the nut must be somewhat smaller than the tap to reduce the possibility of welding the nut and the tap to the job itself. Allow the weld to cool before trying to remove the tap. When the nut, tap, and job have come to room temperature, it is often helpful to heat quickly the immediate area around the hole with an oxyacetylene torch. This quick heating expands the adjacent metal of the work after which the removal of the tap may be less difficult. If

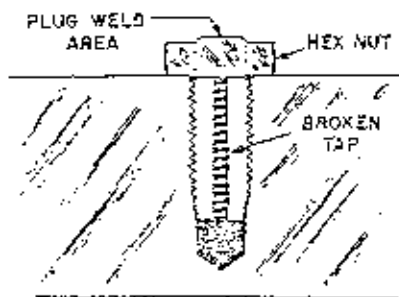


Figure 2-7-26.—Using a plug weld to remove a broken tap.

the heating is too slow, the tap will expand with the adjacent metal of the work and there will be no loosening effect.

SOLDERING

Soldering is used to join metallic surfaces such as copper, iron, nickel, lead, tin, zinc, and aluminum. It is particularly useful for securing electrical connections, joining sheet metal, and sealing seams against leakage. Soldered joints

are not as strong as welded joints, and so are not used where any great mechanical strength is required. Electric soldering irons or guns are widely used for electrical connections, but soldering may also be done with coppers which do not have an electrical heating element.

Soldering requires relatively little equipment. For most soldering jobs, you will need only a source of heat, soldering coppers, solder and a flux. There are several different types of solder and solder fluxes used.

It is important that you understand which solder and flux to use when doing soldering jobs of any kind.

SOURCES OF HEAT

The sources of heat used for soldering with a copper vary according to the method used and the equipment that is available. Welding torches, blowtorches, forges, gas ovens, furnaces, and other heating devices may be used to heat soldering coppers which are used, in turn, to heat the metal being soldered and thus melt the solder. However, the heating devices are sometimes used for direct heating of the surfaces to be joined, in this case, the solder is melted by the heat from the heated surfaces.

New soldering coppers must be tinned (coated with solder) before they are used. If you overheat soldering coppers they must be retinned. After continued use, filing, and retinning, the tip of the copper tends to become too blunt or stubby. A copper in this condition is ineffective and requires forging to reshape its tip.

FORGING A SOLDERING COPPER

To forge a soldering copper, first hold the copper in a vise, gripping the copper itself and not the handle. Then, with a coarse well-chalked file, file the four faces of the tip to remove only the "tin" which is the coating of solder. The chalk on the file helps to keep bits of solder and copper from fouling the file teeth. The coating of solder is removed before the subsequent heating for forging, because it would otherwise cause deep pits to form in the surface of the copper when the copper is brought up to forging temperature. To forge, heat the copper to a dull-red heat by whatever means you have available, noting the color under a shaded light. If heated to a dull-red as viewed in sunlight or other bright light, it will have been overheated to a degree which will cause undesirable pitting of the surface.

Then, referring to figure 2-7-27, forge the copper to approximately the taper that is shown. Too long a taper causes the tip to cool too fast in use. Too short a taper does not produce enough surface area to transfer heat quickly from the copper to the work.

TINNING A SOLDERING COPPER

If a soldering copper is new or has just been forged, it will need to be tinned. To do so hold it in the vise and "dress" the point with a well-chalked file. By "dressing" is meant filing to

remove hammer marks resulting from the forging process and to round off the sharp corners slightly. This is not always required when a tinned copper is to be retinned. Inspection will reveal if it is necessary. Then heat the copper hot enough so that it will readily melt solder. This temperature will be far below the dull-red forging temperature. Try melting solder with the copper frequently as it is being heated, and as soon as it will melt solder, it is ready for tinning.

To tin the copper, first quickly dip it into a jar of dipping solution as shown in figure 2-7-28. Dipping solution is made by dissolving a half

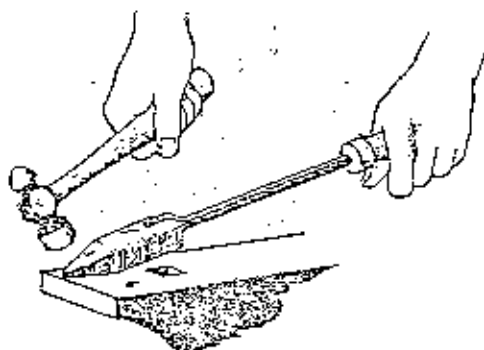


Figure 2-7-27.—Forging a soldering copper.

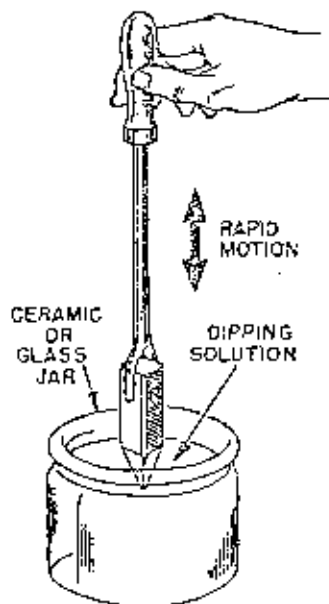


Figure 2-7-28.—Cleaning a soldering copper.

ounce of powdered sal ammoniac in a quart of clean water. If none is available in powdered form, scrape enough off a sal ammoniac block. Dip the copper quickly—in and out—and only an inch deep. This quick dip produces a puff of steam which, along with the chemical action of the solution, "blows off" any dirt and oxides present on the surface of the pointed end of the copper. Notice that the handle of the copper is held between the thumb and index finger with the copper hanging vertically downward. This

affords good wrist action to assure a quick dip to remove the oxides without appreciably cooling the copper.

Then, with the copper cleaned (and still hot because it was dipped quickly into the dipping solution), rub each of its four faces on the sal ammoniac block as shown in figure 2-7-29, adding solder from a roll of solid wire solder or from a bar as indicated in this figure. The sal ammoniac will cause the solder to flow over the faces of the copper and tin them (coat them with solder). The coating is bright and shiny and very thin. It enables the copper, when in use, to pick up beads of solder which will adhere to its surface for transfer to the surface of the work being soldered. Another important function of this tinned surface is to aid in the rapid transfer of heat from the copper, through the tinning, to the work.

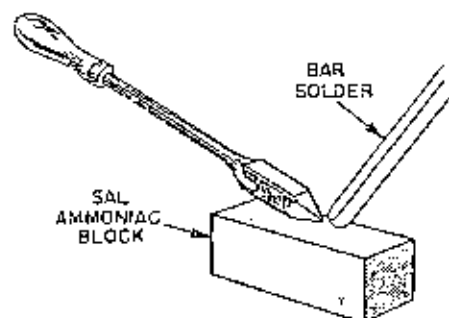


Figure 2-7-29.—Tinning a soldering copper.

Should any scum or dirt picked up from the sal ammoniac block remain on the tinned copper after the tinning process, brush it off with a damp pad of cloth. The damp pad forms steam which, along with the rubbing contact of the pad, will leave the point of the tinned copper bright and clean and ready for use.

SOLDERS

Most soft solders are alloys of tin and lead. Occasionally antimony, silver, arsenic, or bismuth are added to give special properties to the solders. Solders used for joining aluminum are usually alloys of tin and zinc or of tin and cadmium. As mentioned before, soft solders have melting points below 800° F and below the melting points of the metals being joined. The melting points of most tin-lead solders range from about 380° F to about 465° F.

Tin-lead solders are usually identified by numbers which indicate the percentage of tin and the percentage of lead. The first number gives the percentage of tin, the second gives the percentage of lead. For example, a 30/70 solder is an alloy of 30 percent tin and 70 percent lead. A 50/50 solder (sometimes called half-and-half solder) is an alloy of 50 percent tin and 50 percent lead. A 15/85 solder is an alloy of 15 percent tin and 85 percent lead. Solders containing a high percentage of tin are more expensive than those containing a high percentage

of lead. In general, the solders which contain a high percentage of tin have lower melting points than those which contain a high percentage of lead.

Solders are available in various forms, including bars, wires, ingots, and powders. Wire solder is available with or without a flux core.

FLUXES

To make a satisfactory joint, both the metal to be joined and the solder must be free of dirt, grease, oxides, and other foreign matter which would keep the solder from adhering to the metal. Fluxes are used to clean the joint area, to remove the oxide film which is normally present on any metal, and to prevent further oxidation. Fluxes also decrease the surface tension of the solder and thus make the solder a better wetting agent. Table 2-7-1 shows the fluxes that are generally used with some common metals.

Fluxes are generally classified as corrosive, mildly corrosive, and noncorrosive.

Table 2-7-1.—Fluxes Used for Soldering Some Common Metals.

Metals	Fluxes
Brass, copper, tin	Rosin
Lead	Tallow, rosin
Iron, steel	Borax, sal ammoniac
Galvanized iron	Zinc chloride
Zinc	Zinc chloride
Aluminum	Stearine, special flux

CORROSIVE FLUXES have the most effective cleaning action. However, any trace of corrosive flux that remains on the work will cause subsequent corrosion of the metal. Therefore corrosive fluxes are not used for soldering electrical connections and for other work in which subsequent corrosion would present a serious problem.

The most commonly used corrosive fluxes are sal ammoniac (ammonium chloride) and zinc chloride. These fluxes are frequently used in solution or in paste form. The solvent is evaporated as the work is heated, leaving a layer of solid flux on the work. At the soldering temperature, this layer of flux melts and partially decomposes, liberating hydrochloric acid. The hydrochloric acid dissolves the oxides from the surface of the work and from the solder.

Zinc chloride (sometimes called **CUT ACID** or **KILLED ACID**) should be made up in small amounts, as required for use. To prepare zinc chloride, pour a small amount of muriatic acid (the commercial form of hydrochloric acid) into a container. Then add pieces of zinc to the muriatic acid until the liquid no longer boils and bubbles when the zinc is added. The zinc and the acid enter into a chemical reaction which produces zinc chloride and hydrogen gas. When the liquid no longer boils and bubbles, the reaction is complete and the liquid in the container is no

longer muriatic acid; instead, it is now a solution of zinc chloride in water.

Strain the zinc chloride solution before using it as a flux. Any solution which is not used immediately should be stored in a tightly sealed glass container.

Certain precautions must be observed in preparing zinc chloride. Do not inhale the fumes given off by muriatic acid or by the mixture of muriatic acid and zinc; these fumes are injurious to personnel and corrosive to metals. Do not prepare zinc chloride in a closed space. Hydrogen gas is liberated as the zinc reacts chemically with the muriatic acid. **HYDROGEN IS VIOLENTLY EXPLOSIVE!** Zinc chloride should always be prepared out in the open or very near openings to the outside, to minimize the danger of explosion. Also, precautions should be taken to prevent flames or sparks from coming in contact with the liberated hydrogen.

Another type of corrosive flux that you may use is known as **SOLDERING SALTS**. Commercially prepared soldering salts are usually furnished in powder form; the powder is dissolved in water to make a solution.

When a corrosive flux has been used for soldering, the flux residue should be removed from the work as completely as possible. Most corrosive fluxes are soluble in water; washing the work with soap and water and then rinsing thoroughly with clear water usually removes the residue of corrosive fluxes. This cleaning should be done immediately after the soldering has been completed.

MILDLY CORROSIVE FLUXES such as citric acid in water are sometimes used for soldering. These fluxes have some advantages of the more strongly corrosive fluxes and some advantages of the noncorrosive fluxes. The mildly corrosive fluxes clean the surfaces of the work but do not leave a strongly corrosive residue. Mildly corrosive fluxes are generally used for soldering parts which can be rinsed with water after they have been soldered, or for work in which a mildly corrosive residue can be tolerated.

NONCORROSIVE FLUXES are used for soldering electrical connections and for other work which must be completely protected from any trace of corrosive residue. Rosin is the most commonly used noncorrosive flux. In the solid state, rosin is inactive and noncorrosive. When it is heated, it becomes sufficiently active to reduce the oxides on the hot metal and thus perform the fluxing action. Rosin may be obtained in the form of powder, paste, or liquid.

Rosin fluxes frequently leave a brown stain on the soldered metal. This stain is difficult to remove, but it can be prevented to some extent by adding a small amount of turpentine to the rosin. Glycerine is sometimes added to the rosin to make the flux more effective.

METHODS OF SOLDERING

The three soldering methods that you are most likely to use are (1) soldering with coppers, (2) torch soldering, and (3) soldering by

The following general considerations apply to most methods of soldering:

1. Be sure that all surfaces to be soldered are clean and free of oxide, dirt, grease, or other foreign matter.

2. Use a flux which is appropriate for the particular job. Some work requires the use of corrosive fluxes, while other work requires the use of noncorrosive fluxes. Remember that the melting point of the flux must be **BELOW** the melting point of the particular type of solder you are going to use.

3. Heat the surfaces just enough to melt the solder. Solder will not stick to unheated surfaces. However, you should be very careful not to overheat solder, soldering coppers, or surfaces to be joined. In general, solder should not be heated much above the working temperature. As the temperature of molten solder is increased, the rate of oxidation is increased. When molten solder is overheated in air, more tin than lead is lost by oxidation. Any scum formed by oxidation must be skimmed off and discarded. This skimming process changes the proportions of tin and lead remaining in the rest of the solder, since tin and lead oxidize at different rates. When solder must be melted and then carried some distance to the work, it is necessary to heat the solder to a temperature slightly higher than the working temperature. If solder is heated in this manner, protect the surface from oxidation by covering it with a protective mixture of powdered borax, charcoal, and soda.

4. After making a soldered joint, remove as much of the corrosive flux as possible. Ideally, all of the corrosive flux should be removed. In practice, however, it may not be possible to remove all traces of the flux.

SOLDERING SHEET METAL

One way to solder sheet metal is shown in figure 2-7-30. In figure 2-7-30A, you see flux being applied to a lapped seam with a small bristle brush. The flux is applied to both surfaces that are to come into contact, and both surfaces often must be mechanically cleaned first. This means that they must be filed, scraped, or cleaned with abrasive cloth until they are bright. The flux then cleans them chemically to remove oxides. In addition to cleaning the surface, the flux will retard further oxidation and help the solder to flow over the surfaces being joined. The usual flux for tinplate is rosin applied as a powder to be sprinkled on or as the core of rosin core wire solder. The usual flux for sheet metal having a coating of zinc (often called galvanized iron) is zinc chloride. This is an acid sometimes called "cut acid" or "killed acid" and is made by adding zinc, a little at a time to hydrochloric acid, until the acid stops working chemically on zinc. The acid is then said to be "cut" or "killed." A few extra pieces of zinc are usually added to be sure the action is completely stopped. After standing overnight, the liquid is poured through a rag to strain out the residue before it is used

as a flux. Hydrochloric acid is known commercially as muriatic acid and sometimes as "raw acid."

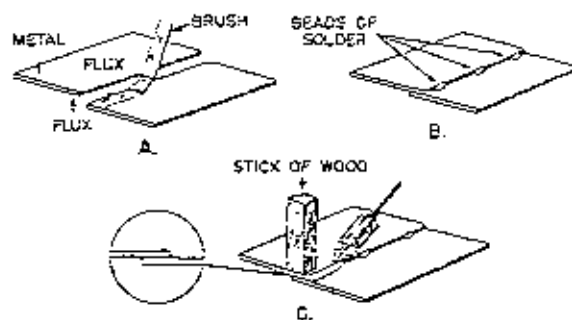


Figure 2-7-30.—Soldering sheet metal.

If galvanized metal is being soldered, cut hydrochloric acid (zinc chloride) may be used as a flux only if the soldering is for the purpose of making the seam air- and water-tight. The mechanical strength of such a seam must be obtained by riveting or other means such as grooving the seam before the soldering is done. Soldering adds little to the strength of the seam because it adheres only to the coating of zinc (the galvanizing) which itself has very limited adherence to the base metal of the sheet. When strength is necessary, and mechanical means cannot be used, use muriatic acid instead of zinc chloride as a flux before applying the solder. This acid will remove the coating of zinc on the galvanized iron so that the solder can adhere directly to the base metal of the sheet and give a strong bond. Be very careful not to splatter muriatic acid on your clothing or on the job. If a drop of acid gets on the job where it should not be, it will remove the protective coating of zinc at that place. If this happens, be sure to flow a little solder over the metal to tin the area and restore the protection. Similarly, when using muriatic acid, be sure that you flow solder over the entire area of the base metal where the galvanizing has been eaten away to restore the protection to the metal. This is done while soldering, and means you sometimes must flow more solder on the base metal than would actually be needed for the seam.

When flux has been applied to both surfaces, put them together as shown in figure 2-7-30B. Place beads of solder along the joint by melting them off the end of a bar of solder right onto the joint or by melting them on the sal ammoniac block and putting them in place, after they have cooled, with your fingers. These drops or beads of solder will flow into the seam when the metal is heated.

Then, as shown in figure 2-7-30C, hold the metal together with a stick of wood (which is a good heat insulator) and place the heated copper with one face flat on the seam. The entire face must be in contact to provide the greatest possible flow of heat from the copper to the work. Hold it there until the nearest bead of solder begins to melt and flow, as it will, into and through the joint, forming a small fillet, as

shown in the inset of figure 2-7-30, on both sides of the seam. In the inset the metal is shown as separated a bit only to indicate that the solder is continuous through the entire lapped seam. Then, maintaining contact with the metal, slowly draw the copper along the length of the seam at the speed necessary for it to melt the beads of solder. When the solder near the stick of wood freezes (solidifies), it will hold the joint and the stick can be moved ahead. Reheat the copper, or take another heated copper, when it no longer melts the solder readily.

Remember that the hot copper heats the metal which in turn melts the solder which then flows through the entire seam. Dropping solder along the seam by holding the copper against a bar of solder in the air a few inches above the seam is not good soldering. However, feeding the solder to the heated metal (heated with the hot copper) which you are soldering, from a coil of wire solder or a bar of bar solder, rather than placing beads along the seam, is another correct way of soldering.

A thorough washing with soda and water after the soldering is completed will remove any remaining flux and prevent corrosion that would otherwise occur.

SOLDERING AN ELECTRICAL CONNECTION

To solder electrical connections, figure 2-7-31, use rosin core solder. The reason for this is that acid core solder, or acid applied with a brush, is usually difficult or impossible to wash off electrical gear. Any acid flux that remains from the soldering operation causes subsequent corrosion which cannot be tolerated. When new wire is being soldered, no mechanical cleaning, such as scraping, is necessary. Old wire, which may have a heavy coating of oxide on its surface, or from which the insulation does not strip off cleanly, may need to be scraped with a knife until it is bright and clean.

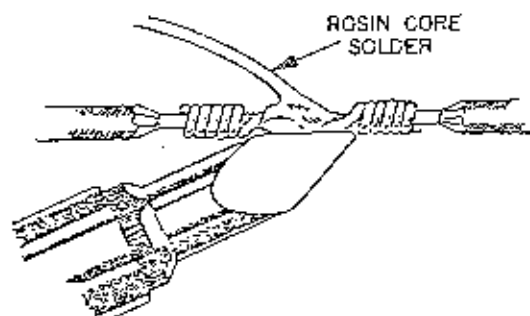


Figure 2-7-31.—Soldering an electrical connection.

To solder electrical connections, hold the soldering iron (copper) beneath the splice being soldered with as much mechanical contact as possible to permit maximum heat transfer. Apply the rosin core solder to the splice. The tinning on the soldering iron aids the transfer of heat to the spliced wire which, when hot enough,

will melt the solder. Before this temperature is reached the rosin core will have melted and run out over the wire to flux the splice. When the solder has coated the splice completely, the job is finished. No extra solder is needed.

NOTE.—The term "soldering iron" is used here because, when this tool is electrically heated with its own heating element, it is usually called an "iron" rather than a "copper." This type is generally used on electrical gear. However, both "iron" and "copper" are sometimes used interchangeably for the tool used for soldering.

TORCH SOLDERING

Torch soldering is often used for small jobs or for work which is relatively hard to reach. A gasoline blowtorch or an alcohol torch may be used for torch soldering.

The general procedure for torch soldering is to play the flames from the torch on to the surfaces to be joined and then apply cold solder in bar or wire form. The heated surfaces will melt the solder. As the solder melts, any excess solder should be wiped off with a damp cloth before it completely hardens.

SOLDERING BY SWEATING

Soldering by sweating is frequently used for making electrical connections. To make a sweated joint, clean and flux each surface to be joined. Then tin each surface. Hold the pieces firmly together and heat the joint with a soldering copper or with a torch until the solder melts and begins to run out. Remove the source of heat and hold the parts firmly in position until the solder completely hardens.

SOLDERING ALUMINUM ALLOYS

Soldering aluminum alloys is more difficult than soldering many other metals. The difficulty arises largely from the fact that aluminum alloys are always covered with a layer of oxide, the thickness of the layer depending on the type of alloy and the conditions to which it has been exposed.

Many aluminum alloys can be successfully soldered, however, if the proper techniques are used. Wrought aluminum alloys are usually—although not always—easier to solder than cast aluminum alloys. Heat-treated aluminum alloys are extremely difficult to solder, as are aluminum alloys containing more than 1 percent magnesium.

The solders used for soldering aluminum alloys are generally tin-zinc or tin-cadmium alloys; they are usually referred to as ALUMINUM SOLDERS. Most of these solders have higher melting points than the tin-lead solders used for ordinary soldering. Both corrosive and noncorrosive fluxes are used for soldering aluminum.

The first step in soldering aluminum is to

clean the surfaces completely and remove the layer of oxide. If a thick layer of oxide is present, remove the main part of it mechanically by filing, scraping, sanding, or wirebrushing. A thin layer of oxide can often be removed by using a corrosive flux; the flux, of course, must be completely removed from the joint after the soldering is finished.

After cleaning and fluxing the surfaces, tin the surfaces with aluminum solder. Apply flux to the work surfaces and to the solder. You can tin the surfaces with a soldering copper or with a torch. If you use a torch, do not apply heat directly to the work surfaces, to the solder, or to the flux. Instead, play the torch on a nearby part of the work and let the heat be conducted through the metal to the work area. Do not use any more heat than is necessary to melt the solder and tin the surfaces. Work the aluminum solder well into the surfaces. After the surfaces have been tinned, the parts may be sweated together.

A procedure that is sometimes used for soldering aluminum alloys is to tin the surfaces with an aluminum solder and then to use a regular tin-lead solder to actually join the tinned surfaces. This procedure may be used when the shape of the parts prevents the use of the sweating method or when a large amount of solder is required to join the parts. When using tin-lead solder with aluminum solder, it is not necessary to use a flux.

Another method of soldering aluminum is by "friction soldering." In this method, a molten pool of solder is deposited on the aluminum. The surface of the aluminum underneath the molten pool is scratched so that the oxide coating is abraded and broken up. The oxide floats to the surface of the solder puddle. The solder then tins the bare aluminum surface from which the oxide has been removed. After such tinning, two aluminum surfaces can easily be joined by applying heat to melt additional solder on the tinned area to form a fillet or to fill the joint.

Although mill files, soldering rods, soldering copper points, and other tools or devices may be used to abrade the oxide film and remove it from the surface of the aluminum, the best device for this purpose is a glass fiber brush. The brush is very easy to use and is more effective than other tools in breaking up the oxide film. When a glass fiber brush is used, the friction soldering process produces better soldered joints than are produced by any other aluminum soldering process.

RIVETING METAL

After metal has been cut and formed, it must be joined together. Most sheet metal seams are either locked or riveted, although some are joined by brazing or welding. This section deals only with joining sheet metal seams by riveting.

SELECTING THE PROPER RIVET

Rivets are available in all of the common

metals, in many lengths and in many diameters. Some of the standard head types are shown in figure 2-7-32.

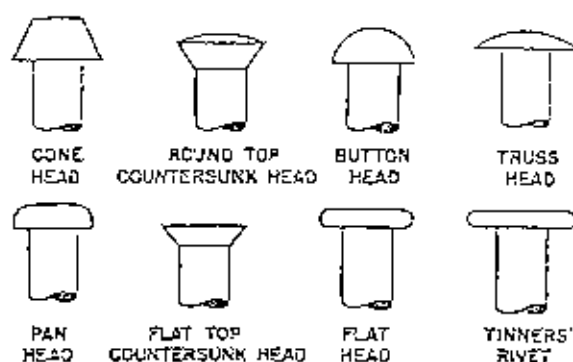


Figure 2-7-32.—Some common types of rivets.

The proper length of rivet to use for a particular job is determined by adding to the grip one and one-half times the rivet diameter. (See fig. 2-7-33C.) This will provide enough metal to form a second "head" at the end of the rivet (fig. 2-7-33A) or to fill the countersunk portion of the hole for flush surfaces as shown in figure 2-7-33B. The grip, as shown in figure 2-7-33, is always measured from face to face of the work, regardless of the type of rivet.

To rivet metal, select the rivet of the proper metal, type of head, and length for the job, and the right diameter.

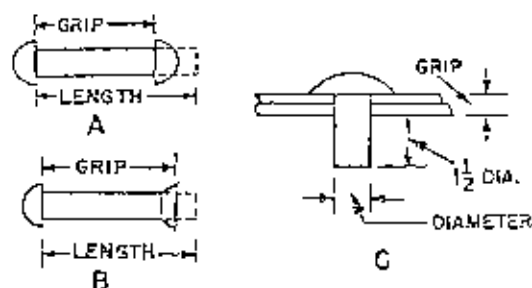


Figure 2-7-33.—Showing what is meant by "grip" of a rivet.

RIVETING SHEET METAL

For sheet metal work, you will probably use tinnert's rivets more than any other kind. Tinnert's rivets vary in size from the 8-ounce rivet to the 16-pound rivet. This size designation indicates the weight of 1000 rivets; thus, if 1000 rivets weigh 8 ounces, each rivet is called an 8-ounce rivet. As the weight per 1000 rivets increases, the diameter and length of the rivets also increase. For example, the 8-ounce rivet has a diameter of 0.089 inch and a length of 5/32 inch, while the 12-pound rivet has a diameter of 0.259 inch and a length of 1/2 inch. For special jobs that require fastening several layers of metal together, special rivets with extra long shanks are used. Table

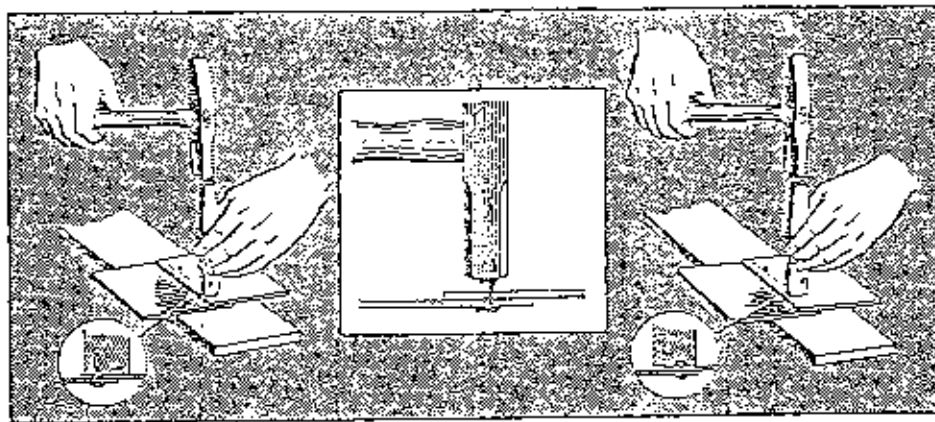


Figure 2-7-34.—Drawing, upsetting, and heading a rivet.

2-7-2 is a guide for selecting rivets of the proper size for sheet metal work.

Rivet spacing is usually given on the blueprint or drawing that you are working from. If the spacing is not indicated, space the rivets according to the service conditions the seam

Table 2-7-2.—Guide for Selecting Rivet Size for Sheet Metal Work.

Gage of sheet metal	Rivet size (weight in pounds per 1000 rivets)
26	1
24	2
22	2 1/2
20	3
18	3 1/2
16	4

must withstand. For example, if the seam must be watertight, you will need many more rivets per inch than if the seam does not need to be watertight. No matter how far apart the rivets are, there must be a distance of at least 2 1/2 times the rivet diameter between the rivets and the edge of the sheet, as measured from the center of the rivet holes to the edge of the sheet.

After you have determined the size and spacing of the rivets, mark the location of the centers of the rivet holes. Then pierce the metal by punching or drilling a small hole. The hole must be slightly larger than the diameter of the rivet to provide a slight clearance.

Riveting involves three operations: drawing, upsetting, and heading. These are illustrated in figure 2-7-34. A rivet set and a riveting hammer are used to perform these operations. The procedure for riveting sheet metal is as follows:

1. Select a rivet set that has a hole slightly larger than the diameter of the rivet.
2. Insert the rivets in the holes and rest the sheets to be joined on a stake or on a solid bench top, with the rivet heads against the stake or bench top.

3. Draw the sheets together by placing the deep hole of the rivet set over the rivet and striking the head of the set with a riveting hammer. Use a light hammer for smaller rivets, a heavier hammer for larger rivets.

4. When the sheets have been properly drawn together, remove the rivet set. Strike the end of the rivet LIGHTLY with the riveting hammer, to upset the end of the rivet. Do not strike too hard a blow, as this would distort the metal around the rivet hold.

5. Place the heading die (dished part) of the rivet set over the upset end of the rivet and form the head. One or two hammer blows on the head of the rivet set will be enough to form the head on the rivet.

A correctly drawn, upset, and headed rivet is shown in the top part of figure 2-7-35. The lower part of this illustration shows the results of incorrect riveting.

When it is necessary to rivet a seam in such a position that you cannot use a stake or a bench top to back up the rivet, a hand dolly may be used as shown in figure 2-7-36.

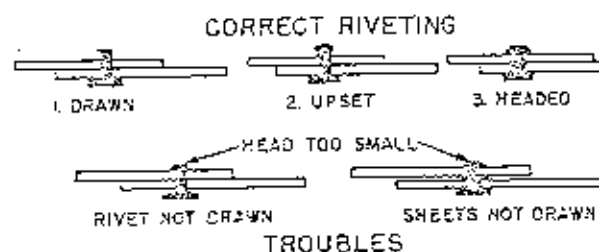


Figure 2-7-35.—Correct and incorrect riveting.

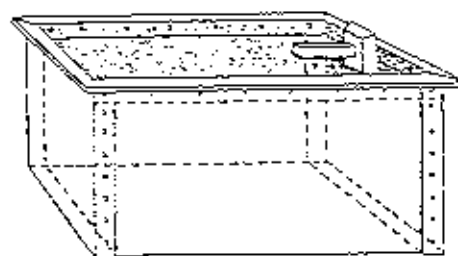


Figure 2-7-36.—Using a hand dolly to back up rivets.

RIVETING A SEAM IN A CYLINDRICAL SECTION

To rivet a seam in a cylindrical structure such as the one shown in figure 2-7-37, use a hollow mandrel stake or some other suitable bar as backing for the rivets. The procedure for riveting a seam in a cylinder is as follows:

1. Insert rivets in the end holes, and slip the pieces over the stake or bar.
2. Draw the seams together and upset the end rivets enough to hold the structure together.
3. Insert the center rivet. Draw, upset, and head this rivet.
4. Complete the seam by riveting from the center to one end and then to the other end. Complete the drawing upsetting, and heading of each rivet as you work along the seam.

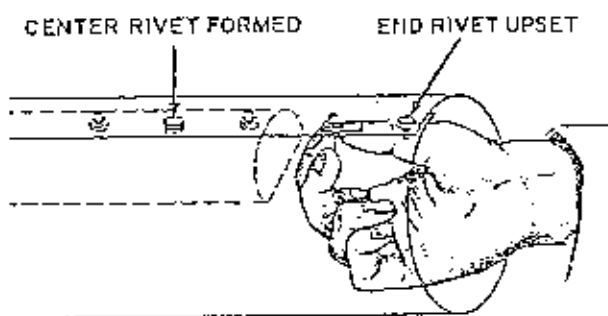


Figure 2-7-37.—Riveting a seam in a cylindrical section.

RIVETING METAL, USING LARGE RIVETS

To rivet metal with rivets too large to permit the use of a rivet set, set the rivet by striking the metal around the rivet with a hammer (fig. 2-7-38) or by striking a punch (fig. 2-7-38B) while working it around the rivet to force the two pieces of metal together and against the head of the rivet. Then mushroom the rivet, as shown in figure 2-7-38C, using several flat blows if necessary with the face of the hammer. Finally, to give the mushroom a rounded form, work around it with the ball peen of the hammer, striking angled blows until a second head is formed (See fig. 2-7-38D.)

To upset (mushroom or flatten) rivets when the second head is to be a countersunk head, countersink the stock and insert the rivet as shown in figure 2-7-39A. After setting the

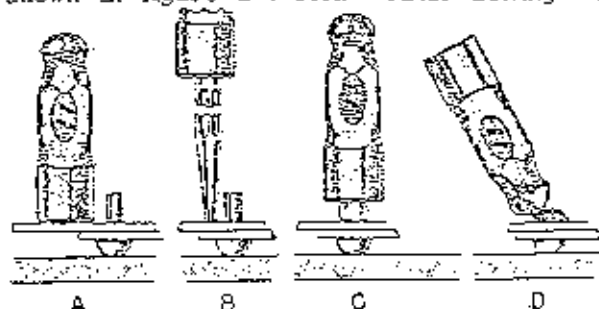


Figure 2-7-38.—Riveting metal, using large rivets.

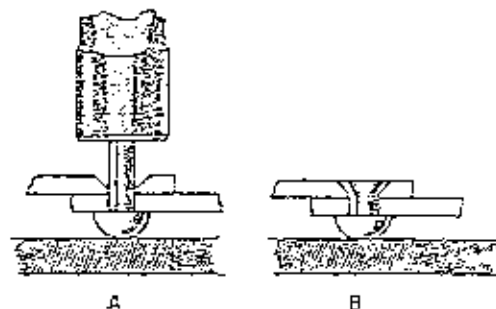


Figure 2-7-39.—Upsetting a rivet that is countersunk.

rivet, either with or without a rivet set, strike the rivet with the face of the hammer to force the metal into the countersunk hole. In figure 2-7-39B the rivet was just the right length to fill the countersunk hole. A too-short rivet will not fill the countersunk hole and a too-long rivet can be left slightly high or be filed, round, or otherwise cut flush with the surface if necessary.

STAMPING LETTERS AND FIGURES ON METAL

To stamp letters and figures on ferrous metal (cast iron or steel), first test it with a sharp mill file. If a sharp mill file will "take hold" and cut the metal, this indicates that the surface is soft enough to stamp without damaging the steel letters and figures used for stamping. Nonferrous metals are safe to stamp without testing. They are—even when heat treated—softer than the steel letters and figures.

Draw a guideline on the job and follow it as you stamp each letter and figure just above the line (See fig. 2-7-40.) Hold the steel letter or figure between your thumb and two fingers and strike only one blow for each impression. To determine how hard to strike the tool with the hammer, make a trial run on a test piece of the same metal.

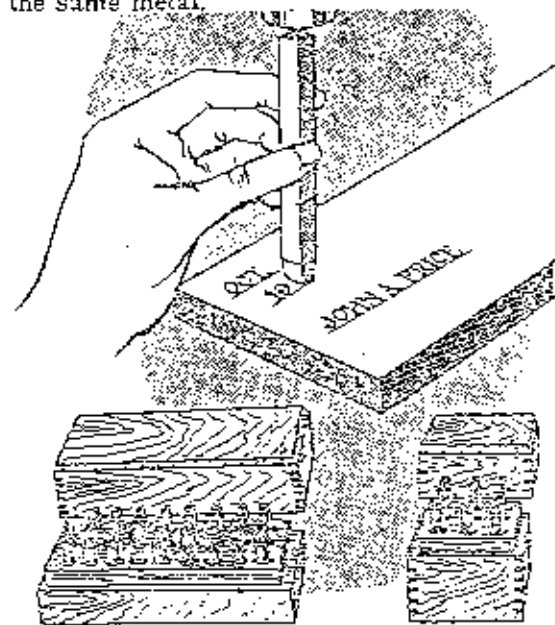


Figure 2-7-40.—Stamping letters and rivets on metal.

Review Questions

1. How are most metal-headed hammers classified as to size?
2. What materials are heads of soft-faced hammers generally made of?
3. A combination-wrench is a combination of what two types of wrenches?
4. Why should a wrench be pulled rather than pushed?
5. What type of wrench may a hammer be used on?
6. Under what conditions would a torque wrench be used?
7. What information should be available before using a torque wrench?
8. What is generally considered to be the best all-around wrench for light work?
9. What is the purpose of spanner wrenches?
10. Recessed-head screws which have hex-shaped (six-sided) recess call for which type of wrench?
11. What are some of the basic rules to keep in mind when using wrenches?
12. Name two types of screwdrivers.
13. When using a screwdriver why is it important to select the proper size blade?
14. Screwdrivers with square shanks are used for what purpose?
15. What is a pinch bar used for?
16. Name several types of pliers.
17. Name several types of metal cutting tools.
18. When cutting medium or heavy-gage metal with snips, why is it important to cut outside the layout line?
19. When using a hacksaw, how much downward pressure should be applied--(a) on the forward stroke? (b) on the back stroke?
20. Name several types of chisels.
21. Swiss-Pattern or Jewelers files are used on what type of work?
22. What is the purpose of a file card?
23. Why should a file never be used as a pry?
24. What is the purpose of a reamer?
25. What is the purpose of a countersink?
26. Name two parts of a twist drill.
27. What are the most common types of taps?
28. Tube cutters should only be used to cut which metals?
29. Name several types of woodworking saws.
30. What is the purpose of a vernier scale on a micrometer?
31. Under what conditions should simple calipers be used?
32. Name several types of micrometers and explain their use.
33. For what purposes are squares used?
34. A thickness (feeler) gage is used for what purpose?
35. What are the two types of power used to drive power tools?
36. When using electric power tools, why is it important to properly ground the tools?
37. A belt sander is superior to a disk sander for smoothing the flat surfaces of boards. Why?
38. What does the term 8-32 mean when applied to machine screws?
39. Some cap screw heads have drilled holes. Why?
40. Under what conditions would setscrews be used and why?
41. Why are washers used?
42. What is a pilot hole?
43. This note may appear on a blueprint: 3/4-16NF-3
 - (a) What does the 3/4 indicate?
 - (b) What does the 16 mean?
 - (c) What is the meaning of NF?
 - (d) What does the last number 3 indicate?
44. Describe the term laying out?
45. The mushroom head of a chisel refers to what? How would this condition be remedied?
46. Prior to using a twist drill on brass, what must be done to the drill and why?

Review Questions (Continued)

47. Counter boring refers to what?
48. Hacksaws having 32 teeth per inch are used to cut what type of materials?
49. Does a glass cutter actually cut the glass? Explain.
50. Describe how a mechanic would remove a broken bolt and retap the hole?
51. How is metal, to be stamped with letter dies, tested to be sure the metal will not damage the letter dies?

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DECIMAL EQUIVALENTS OF INCH AND FOOT

Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions
$\frac{1}{64}$	.0052	$\frac{1}{16}$	$\frac{17}{64}$	.2552	$3\frac{1}{16}$	$\frac{33}{64}$	.5052	$6\frac{1}{16}$	$\frac{49}{64}$	.7552	$9\frac{1}{16}$
	.0104	$\frac{1}{8}$		.2604	$3\frac{1}{8}$		.5104	$6\frac{1}{8}$		.7604	$9\frac{1}{8}$
	.015625	$\frac{3}{16}$		.265625	$3\frac{3}{16}$		.515625	$6\frac{3}{16}$		.765625	$9\frac{3}{16}$
	.0208	$\frac{1}{4}$		.2708	$3\frac{1}{4}$		.5208	$6\frac{1}{4}$		.7708	$9\frac{1}{4}$
$\frac{1}{32}$	.0260	$\frac{5}{16}$	$\frac{9}{32}$	.2760	$3\frac{5}{16}$	$\frac{17}{32}$	.5260	$6\frac{5}{16}$	$\frac{25}{32}$	.7760	$9\frac{5}{16}$
	.03125	$\frac{3}{8}$		.28125	$3\frac{3}{8}$		.53125	$6\frac{3}{8}$		.78125	$9\frac{3}{8}$
	.0365	$\frac{7}{16}$		.2865	$3\frac{7}{16}$		.5365	$6\frac{7}{16}$		.7865	$9\frac{7}{16}$
	.0417	$\frac{1}{2}$		.2917	$3\frac{1}{2}$		.5417	$6\frac{1}{2}$		.7917	$9\frac{1}{2}$
$\frac{3}{64}$	.046875	$\frac{9}{16}$	$\frac{19}{64}$	.296875	$3\frac{9}{16}$	$\frac{35}{64}$	.546875	$6\frac{9}{16}$	$\frac{51}{64}$	.796875	$9\frac{9}{16}$
	.0521	$\frac{5}{8}$		.3021	$3\frac{5}{8}$		.5521	$6\frac{5}{8}$		.8021	$9\frac{5}{8}$
	.0573	$\frac{11}{16}$		.3073	$3\frac{11}{16}$		.5573	$6\frac{11}{16}$		.8073	$9\frac{11}{16}$
	.0625	$\frac{3}{4}$		.3125	$3\frac{3}{4}$		.5625	$6\frac{3}{4}$		.8125	$9\frac{3}{4}$
$\frac{1}{16}$	.0677	$\frac{13}{16}$	$\frac{5}{16}$	.3177	$3\frac{13}{16}$	$\frac{9}{16}$	.5677	$6\frac{13}{16}$	$\frac{13}{16}$	.8177	$9\frac{13}{16}$
	.0729	$\frac{7}{8}$		.3229	$3\frac{7}{8}$		.5729	$6\frac{7}{8}$		.8229	$9\frac{7}{8}$
	.078125	$\frac{15}{16}$		.328125	$3\frac{15}{16}$		.578125	$6\frac{15}{16}$		.828125	$9\frac{15}{16}$
	.0833	1		.3333	4		.5833	7		.8333	10
$\frac{1}{8}$	.0885	$1\frac{1}{8}$	$\frac{11}{32}$	.3385	$4\frac{1}{8}$	$\frac{19}{32}$	.5885	$7\frac{1}{8}$	$\frac{27}{32}$	.8385	$10\frac{1}{8}$
	.09375	$1\frac{1}{4}$		.34375	$4\frac{1}{4}$		.59375	$7\frac{1}{4}$		.84375	$10\frac{1}{4}$
	.0990	$1\frac{1}{2}$		.3490	$4\frac{1}{2}$		.5990	$7\frac{1}{2}$		.8490	$10\frac{1}{2}$
	.1042	$1\frac{3}{4}$		.3542	$4\frac{3}{4}$		.6042	$7\frac{3}{4}$		.8542	$10\frac{3}{4}$
$\frac{7}{32}$	.109375	$1\frac{5}{8}$	$\frac{23}{64}$	.359375	$4\frac{5}{8}$	$\frac{31}{64}$	.609375	$7\frac{5}{8}$	$\frac{55}{64}$	.859375	$10\frac{5}{8}$
	.1146	$1\frac{3}{4}$		.3646	$4\frac{3}{4}$		.6146	$7\frac{3}{4}$		.8646	$10\frac{3}{4}$
	.1198	$1\frac{7}{8}$		.3698	$4\frac{7}{8}$		.6198	$7\frac{7}{8}$		.8698	$10\frac{7}{8}$
	.1250	2		.3750	4		.6250	8		.8750	11
$\frac{1}{8}$	.1302	$1\frac{1}{8}$	$\frac{3}{8}$	.3802	$4\frac{1}{8}$	$\frac{5}{8}$	.6302	$4\frac{1}{8}$	$\frac{7}{8}$	.8802	$10\frac{1}{8}$
	.1354	$1\frac{1}{4}$		.3854	$4\frac{1}{4}$		.6354	$4\frac{1}{4}$		.8854	$10\frac{1}{4}$
	.140625	$1\frac{1}{2}$		.390625	$4\frac{1}{2}$		.640625	$4\frac{1}{2}$		.890625	$10\frac{1}{2}$
	.1458	$1\frac{3}{4}$		.3958	$4\frac{3}{4}$		.6458	$4\frac{3}{4}$		.8958	$10\frac{3}{4}$
$\frac{5}{16}$	.1510	$1\frac{1}{2}$	$\frac{13}{16}$	.4010	$4\frac{1}{2}$	$\frac{21}{16}$	.6510	$4\frac{1}{2}$	$\frac{29}{16}$	.9010	$10\frac{1}{2}$
	.15625	$1\frac{1}{4}$		.40625	$4\frac{1}{4}$		.65625	$4\frac{1}{4}$		.90625	$10\frac{1}{4}$
	.1615	$1\frac{1}{8}$		.4115	$4\frac{1}{8}$		.6615	$4\frac{1}{8}$		.9115	$10\frac{1}{8}$
	.1667	$1\frac{1}{2}$		.4167	$4\frac{1}{2}$		.6667	$4\frac{1}{2}$		.9167	$10\frac{1}{2}$
$\frac{1}{4}$	.171875	$1\frac{3}{8}$	$\frac{27}{64}$	.421875	$5\frac{1}{8}$	$\frac{43}{64}$	.671875	$8\frac{1}{8}$	$\frac{59}{64}$	.921875	$11\frac{1}{8}$
	.1771	$1\frac{1}{2}$		.4271	$5\frac{1}{2}$		.6771	$8\frac{1}{2}$		.9271	$11\frac{1}{2}$
	.1823	$1\frac{5}{8}$		.4323	$5\frac{5}{8}$		.6823	$8\frac{5}{8}$		.9323	$11\frac{5}{8}$
	.1875	$1\frac{3}{4}$		.4375	$5\frac{3}{4}$		.6875	$8\frac{3}{4}$		.9375	$11\frac{3}{4}$
$\frac{3}{16}$	.1927	$1\frac{7}{8}$	$\frac{7}{16}$	.4427	$5\frac{7}{8}$	$\frac{11}{16}$	.6927	$8\frac{7}{8}$	$\frac{15}{16}$	.9427	$11\frac{7}{8}$
	.1979	$1\frac{9}{8}$		.4479	$5\frac{9}{8}$		.6979	$8\frac{9}{8}$		.9479	$11\frac{9}{8}$
	.203125	$1\frac{1}{2}$		.453125	$5\frac{1}{2}$		.703125	$8\frac{1}{2}$		.953125	$11\frac{1}{2}$
	.2083	$1\frac{3}{4}$		.4583	$5\frac{3}{4}$		.7083	$8\frac{3}{4}$		.9583	$11\frac{3}{4}$
$\frac{1}{8}$	.2135	$1\frac{1}{4}$	$\frac{15}{32}$	.4635	$5\frac{1}{4}$	$\frac{23}{32}$	.7135	$8\frac{1}{4}$	$\frac{31}{32}$	.9635	$11\frac{1}{4}$
	.21875	$1\frac{1}{2}$		.46875	$5\frac{1}{2}$		.71875	$8\frac{1}{2}$		.96875	$11\frac{1}{2}$
	.2240	$1\frac{3}{4}$		.4740	$5\frac{3}{4}$		.7240	$8\frac{3}{4}$		.9740	$11\frac{3}{4}$
	.2292	$1\frac{5}{8}$		.4792	$5\frac{5}{8}$		.7292	$8\frac{5}{8}$		.9792	$11\frac{5}{8}$
$\frac{5}{32}$	.234375	$1\frac{3}{8}$	$\frac{31}{64}$	.484375	$7\frac{1}{8}$	$\frac{47}{64}$	.734375	$9\frac{1}{8}$	$\frac{63}{64}$	.984375	$12\frac{1}{8}$
	.2396	$1\frac{1}{2}$		.4896	$7\frac{1}{2}$		.7396	$9\frac{1}{2}$		.9896	$12\frac{1}{2}$
	.2448	$1\frac{5}{8}$		.4948	$7\frac{5}{8}$		.7448	$9\frac{5}{8}$		.9948	$12\frac{5}{8}$
	.2500	2		.5000	8		.7500	10		1.0000	12

Decimal Equivalents of Number Size Drills

No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches	No.	Size of Drill in Inches
1	.2250	21	.1390	41	.0960	61	.0390
2	.2210	22	.1370	42	.0935	62	.0380
3	.2130	23	.1340	43	.0890	63	.0370
4	.2090	24	.1320	44	.0860	64	.0360
5	.2055	25	.1405	45	.0820	65	.0350
6	.2040	26	.1470	46	.0810	66	.0330
7	.2010	27	.1440	47	.0785	67	.0320
8	.1990	28	.1405	48	.0760	68	.0310
9	.1960	29	.1360	49	.0730	69	.0292
10	.1935	30	.1285	50	.0700	70	.0280
11	.1910	31	.1200	51	.0670	71	.0260
12	.1890	32	.1160	52	.0635	72	.0250
13	.1850	33	.1130	53	.0595	73	.0240
14	.1820	34	.1110	54	.0550	74	.0225
15	.1800	35	.1100	55	.0520	75	.0210
16	.1770	36	.1065	56	.0465	76	.0200
17	.1730	37	.1040	57	.0430	77	.0180
18	.1695	38	.1015	58	.0420	78	.0160
19	.1660	39	.0995	59	.0410	79	.0145
20	.1610	40	.0980	60	.0400	80	.0135

Decimal Equivalents of Letter Size Drills

Letter	Size of Drill in Inches	Letter	Size of Drill in Inches
A	.234	N	.302
B	.238	O	.316
C	.242	P	.323
D	.246	Q	.332
E	.250	R	.339
F	.257	S	.348
G	.261	T	.358
H	.266	U	.368
I	.272	V	.377
J	.277	W	.386
K	.281	X	.397
L	.290	Y	.404
M	.295	Z	.413

Different Standards for Wire Gages

in use in the United States

Dimensions of Sizes in Decimal Parts of an Inch

Number of Wire Gage	American or Brown & Sharpe	Birmingham or Stubbs' Iron Wire	Washburn & Moen, Worcester, Mass.	W. & M. Steel Music Wire	American S. & W. Co's. Music Wire Gage	Imperial Wire Gage	Stubbs' Steel Wire	U.S. Standard Gage for Sheet and Plate Iron and Steel	Number of Wire Gage
00000000				.0083					00000000
0000000				.0087					0000000
000000				.0095	.004	.464		.46875	000000
00000				.010	.005	.432		.4375	00000
0000	.480	.454	.3938	.011	.006	.400		.40625	0000
000	.40964	.425	.3625	.012	.007	.372		.375	0000
00	.3648	.380	.3310	.0133	.008	.348		.34375	000
0	.32486	.340	.3065	.0144	.009	.324		.3125	00
1	.2893	.300	.2830	.0156	.010	.300	.227	.28125	1
2	.25763	.284	.2625	.0166	.011	.276	.219	.265625	2
3	.22942	.259	.2437	.0178	.012	.252	.212	.250	3
4	.20431	.238	.2253	.0188	.013	.232	.207	.234375	4
5	.18194	.220	.2070	.0202	.014	.212	.204	.21875	5
6	.16202	.203	.1920	.0215	.016	.192	.201	.203125	6
7	.14428	.180	.1770	.023	.018	.176	.199	.1875	7
8	.12849	.165	.1620	.0243	.020	.160	.197	.171875	8
9	.11443	.148	.1483	.0256	.022	.144	.194	.15625	9
10	.10180	.134	.1350	.027	.024	.128	.191	.140625	10
11	.090742	.120	.1205	.0284	.026	.116	.188	.125	11
12	.080808	.109	.1055	.0296	.029	.104	.185	.109375	12
13	.071961	.095	.0915	.0314	.031	.092	.182	.09375	13
14	.064084	.083	.0800	.0326	.033	.080	.180	.078125	14
15	.057088	.072	.0720	.0345	.035	.072	.178	.0703125	15
16	.05082	.065	.0625	.036	.037	.064	.175	.0625	16
17	.045257	.058	.0540	.0377	.039	.056	.172	.05625	17
18	.040303	.049	.0475	.0395	.041	.048	.168	.050	18
19	.03589	.042	.0410	.0414	.043	.040	.164	.04375	19
20	.031961	.035	.0348	.0434	.045	.036	.161	.0375	20
21	.028462	.032	.03175	.046	.047	.032	.157	.034375	21
22	.025347	.028	.0286	.0483	.049	.028	.155	.03125	22
23	.022571	.025	.0258	.051	.051	.024	.153	.028125	23
24	.0201	.022	.0230	.055	.055	.022	.151	.025	24
25	.0179	.020	.0204	.0586	.059	.020	.148	.021875	25
26	.01594	.018	.0181	.0626	.063	.018	.146	.01875	26
27	.014193	.016	.0173	.0658	.067	.0164	.143	.0171875	27
28	.012641	.014	.0162	.072	.071	.0149	.139	.015625	28
29	.011257	.013	.0150	.076	.075	.0136	.134	.0140625	29
30	.010025	.012	.0140	.080	.080	.0124	.127	.0125	30
31	.008928	.010	.0132		.085	.0116	.120	.0109375	31
32	.00795	.009	.0125		.090	.0108	.115	.01015625	32
33	.00708	.008	.0112		.095	.0100	.112	.009375	33
34	.006304	.007	.0104			.0092	.110	.00859375	34
35	.005614	.005	.0095			.0084	.108	.0078125	35
36	.005	.004	.0090			.0076	.106	.00703125	36
37	.004453					.0068	.103	.00640625	37
38	.003965					.0060	.101	.00625	38
39	.003531					.0052	.099		39
40	.003144					.0048	.097		40

DRILL SIZES—FRACTIONAL, NUMBER, LETTER—TO DECIMAL INCHES

Fractional Size Drill Inches	Size Drill	Decimal Inches	Fractional Size Drill Inches	Size Drill	Decimal Inches	Fractional Size Drill Inches	Size Drill	Decimal Inches	Fractional Size Drill Inches	Size Drill	Decimal Inches	Fractional Size Drill Inches	Size Drill	Decimal Inches
1/64	80	.0156	3/64	40	.0375	11/64	21	.1679	3/16	17	.2656	5/16	11	.3125
	79	.0154		39	.0370		20	.1649		16	.2500		10	.3125
	78	.0152		38	.0365		19	.1620		15	.2344		9	.3125
	76	.0150		37	.0360		18	.1594		14	.2271		8	.3125
	75	.0148		36	.0354		17	.1567		13	.2148		7	.3125
	74	.0146		35	.0349		16	.1540		12	.2020		6	.3125
	73	.0144		34	.0344		15	.1513		11	.1891		5	.3125
	72	.0142		33	.0339		14	.1486		10	.1864		4	.3125
	71	.0140		32	.0334		13	.1459		9	.1837		3	.3125
	70	.0138		31	.0329		12	.1432		8	.1809		2	.3125
1/32	69	.0136	1/8	24	.0312	7/32	9	.2188	1/2	1	.5000	3/4	1	.7500
	68	.0134		23	.0307		8	.2160		1/2	.5000		3/4	.7500
	67	.0132		22	.0302		7	.2133		1/2	.5000		3/4	.7500
	66	.0130		21	.0297		6	.2106		1/2	.5000		3/4	.7500
	65	.0128		20	.0292		5	.2079		1/2	.5000		3/4	.7500
	64	.0126		19	.0287		4	.2052		1/2	.5000		3/4	.7500
	63	.0124		18	.0282		3	.2025		1/2	.5000		3/4	.7500
	62	.0122		17	.0277		2	.2000		1/2	.5000		3/4	.7500
	61	.0120		16	.0272		1	.1975		1/2	.5000		3/4	.7500
	60	.0118		15	.0267		1/2	.1950		1/2	.5000		3/4	.7500
3/64	59	.0116	5/64	12	.0250	15/64	7	.2344	1	0	.0000	1 1/4	0	.0000
	58	.0114		11	.0245		6	.2317		1	.0000		1 1/4	.0000
	57	.0112		10	.0240		5	.2290		1	.0000		1 1/4	.0000
	56	.0110		9	.0235		4	.2263		1	.0000		1 1/4	.0000
	55	.0108		8	.0230		3	.2236		1	.0000		1 1/4	.0000
	54	.0106		7	.0225		2	.2210		1	.0000		1 1/4	.0000
	53	.0104		6	.0220		1	.2183		1	.0000		1 1/4	.0000
	52	.0102		5	.0215		1/2	.2156		1	.0000		1 1/4	.0000
	51	.0100		4	.0210		1/4	.2130		1	.0000		1 1/4	.0000
	50	.0098		3	.0205		1/8	.2103		1	.0000		1 1/4	.0000
1/16	49	.0096	3/32	2	.0200	1/4	1/4	.2077	1 1/2	0	.0000	2	0	.0000
	48	.0094		1	.0195		1/8	.2050		1 1/2	.0000		2	.0000
	47	.0092		1/2	.0190		1/16	.2023		1 1/2	.0000		2	.0000
	46	.0090		1/4	.0185		3/32	.2000		1 1/2	.0000		2	.0000
	45	.0088		1/8	.0180		1/16	.1975		1 1/2	.0000		2	.0000
	44	.0086		3/16	.0175		1/32	.1950		1 1/2	.0000		2	.0000
	43	.0084		1/4	.0170		1/64	.1925		1 1/2	.0000		2	.0000
	42	.0082		3/32	.0165		1/128	.1900		1 1/2	.0000		2	.0000
	41	.0080		1/8	.0160		1/256	.1875		1 1/2	.0000		2	.0000
	40	.0078		1/16	.0155		1/512	.1850		1 1/2	.0000		2	.0000
	39	.0076		1/32	.0150		1/1024	.1825		1 1/2	.0000		2	.0000

STANDARD KEYWAYS AND SETSCREWS

Diameter of Shaft	Keyway Width x Depth	Diameter of Setscrew	Diameter of Shaft	Keyway Width x Depth	Diameter of Setscrew
1/8" - 3/8"	1/16" x 1/64"	1/16"	2 1/8" - 2 3/4"	1 1/2" x 1/2"	1 1/2"
1/2" - 1 1/8"	3/16" x 1/32"	3/16"	2 3/8" - 3 1/2"	1 3/4" x 1/2"	1 3/4"
1 1/4" - 1 3/4"	1/2" x 1/16"	1/2"	3 1/2" - 3 3/4"	1 7/8" x 1/2"	1 7/8"
1 3/4" - 1 7/8"	5/8" x 1/16"	5/8"	3 3/4" - 4 1/2"	2" x 1/2"	2"
1 7/8" - 1 3/4"	1" x 1/16"	1"	4 1/2" - 5 1/2"	2 1/4" x 1/2"	2 1/4"
1 3/4" - 2 1/8"	1 1/8" x 1/16"	1 1/8"	5 1/2" - 6 1/2"	2 3/4" x 1/2"	2 3/4"
			6 1/2" - 7 1/2"	3" x 1/2"	3"
			7 1/2" - 8 1/2"	3 1/4" x 1/2"	3 1/4"

COMMON CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN	MULTIPLY	BY	TO OBTAIN
Atmospheres	14.7	psi	Feet of water	.433	psi
Atmospheres	29.9	Inch. of Mercury	Feet of water	.884	Inches of Hg.
B.T.U.	.0005929	H.P. hr.	Foot pounds min	3.0503 x 10 ⁻⁵	Horsepower
Centimeters	.3937	Inches	Gallons	3.785.43	cubic cm.
Centistokes	.001552	in. ² sec.	Gallons	231.	cubic in.
Cubic centimeters	.06102	cu. in.	Gallons	.83268	gallon (imp.)
Cubic centimeters	.002642	gallons (liq.)	Horsepower	550.	ft. lbs./sec.
Cubic feet	1736.	cubic in.	Inches of Hg.	.489	psi
Cubic inches	.004329	gallons	psi	.06804	atmospheres
Cubic inches	16.387	cubic cm.	psi	2.04179	Inches of Hg.
Dynes	2.24809 x 10 ⁻⁶	Pounds	psi	2.31	feet of water
Dynes /sq. cm.	1.45038 x 10 ⁻⁸	psi			

TAP DRILL SIZES

The common nut, drilled out so that it only contains 50% of a full depth thread, will break the bolt before it will strip. A full depth of thread in a common nut is only about 50% stronger than a 75% depth of thread, yet it requires three times the power to tap. Drill sizes shown allow for 75% depth of thread, as this normally gives the maximum strength for safety, and is also economical in tapping.

U.N.C. & N.C.	NATIONAL COARSE	OLD U.S.S.	U.N.F. & N.F.	NATIONAL FINE	OLD S.A.E.
TAP	THREADS PER INCH	TAP DRILL	TAP	THREADS PER INCH	TAP DRILL
$\frac{1}{16}$	20	No. 7	$\frac{1}{16}$	28	No. 3
$\frac{1}{8}$	18	F	$\frac{1}{8}$	24	1
$\frac{1}{4}$	16	$\frac{1}{8}$	$\frac{1}{4}$	24	0
$\frac{3}{8}$	14	U	$\frac{3}{8}$	20	$\frac{1}{16}$
$\frac{1}{2}$	12	$\frac{1}{4}$	$\frac{1}{2}$	20	$\frac{1}{8}$
$\frac{5}{8}$	12	$\frac{3}{8}$	$\frac{5}{8}$	18	$\frac{3}{16}$
$\frac{3}{4}$	11	$\frac{1}{2}$	$\frac{3}{4}$	18	$\frac{1}{4}$
$\frac{7}{8}$	11	$\frac{5}{8}$	$\frac{7}{8}$	16	$\frac{5}{16}$
$1\frac{1}{8}$	10	$\frac{3}{4}$	$1\frac{1}{8}$	16	$\frac{3}{8}$
$1\frac{1}{4}$	9	$1\frac{1}{8}$	$1\frac{1}{4}$	14	$\frac{1}{2}$
$1\frac{1}{2}$	8	$1\frac{1}{4}$	$1\frac{1}{2}$	14	$\frac{5}{8}$
$1\frac{3}{4}$	7	$1\frac{3}{4}$	$1\frac{3}{4}$	12	$\frac{3}{4}$
$2\frac{1}{4}$	7	$2\frac{1}{4}$	$2\frac{1}{4}$	12	$1\frac{1}{8}$
$2\frac{1}{2}$	6	$2\frac{1}{2}$	$2\frac{1}{2}$	12	$1\frac{1}{4}$
$2\frac{3}{4}$	6	$2\frac{3}{4}$	$2\frac{3}{4}$	12	$1\frac{3}{8}$

The Tap Drill Sizes above are for use with Plug Taps
*Not U.N.F.

MACHINE SCREW SIZES

NUMBER SIZES OF TAP	THREADS PER INCH	TAP DRILL	CLEARANCE DRILL
0	60	No. 55	No. 52
1	72	No. 50	No. 48
2	56	No. 51	No. 49
3	48	No. 47	No. 38
4	40	No. 44	No. 32
6	32	No. 35	No. 27
8	32	No. 29	No. 22
10	24	No. 25	No. 9
10	32	No. 21	No. 9
12	24	No. 17	No. 1
$\frac{1}{16}$	20	No. 7	$\frac{1}{16}$
$\frac{1}{8}$	28	No. 3	$\frac{1}{8}$
$\frac{1}{4}$	18	F	$\frac{1}{4}$
$\frac{3}{8}$	24	1	$\frac{3}{8}$
$\frac{1}{2}$	16	$\frac{1}{8}$	$\frac{1}{2}$
$\frac{5}{8}$	24	0	$\frac{5}{8}$

American Standard PIPE SIZES Tapered Dryseal

TAP	THREADS PER INCH	TAP DRILL	CLEARANCE DRILL
$\frac{1}{8}$	27	R	$\frac{1}{8}$
$\frac{1}{4}$	18	$\frac{1}{8}$	$\frac{1}{4}$
$\frac{3}{8}$	18	$\frac{1}{4}$	$\frac{3}{8}$
$\frac{1}{2}$	14	$\frac{3}{8}$	$\frac{1}{2}$
$\frac{5}{8}$	14	$\frac{1}{2}$	$\frac{5}{8}$
1	11 $\frac{1}{2}$	1 $\frac{1}{8}$	1 $\frac{1}{2}$
1 $\frac{1}{8}$	11 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$
1 $\frac{1}{4}$	11 $\frac{1}{2}$	1 $\frac{3}{8}$	2
2	11 $\frac{1}{2}$	2 $\frac{1}{8}$	2 $\frac{1}{2}$
2 $\frac{1}{2}$	8	2 $\frac{1}{4}$	3
3	8	3 $\frac{1}{4}$	3 $\frac{1}{2}$
3 $\frac{1}{2}$	8	3 $\frac{3}{4}$	4 $\frac{1}{2}$
4	8	4 $\frac{1}{2}$	4 $\frac{1}{2}$

DECIMAL EQUIVALENTS OF DIAMETERS

DIAMETERS								
$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	DECIMAL EQUIVALENT	CIRCUM	AREA
$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	.015625	.0491	.0002
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{1}$	.03125	.0982	.0008
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.046875	.1473	.0017
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.0625	.1963	.0021
$\frac{3}{4}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.078125	.2454	.0028
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.09375	.2945	.0036
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.109375	.3436	.0044
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.125	.3927	.0123
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.140625	.4418	.0155
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.15625	.4909	.0192
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.171875	.5400	.0232
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.1875	.5890	.0276
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.203125	.6381	.0324
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.21875	.6872	.0375
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.234375	.7363	.0431
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.25	.7854	.0491
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.265625	.8345	.0554
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.28125	.8836	.0621
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.296875	.9327	.0692
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.3125	.9817	.0767
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.328125	1.031	.0846
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.34375	1.080	.0928
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.359375	1.129	.1014
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.375	1.178	.1104
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.390625	1.227	.1198
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.40625	1.276	.1296
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.421875	1.325	.1398
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.4375	1.374	.1503
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.453125	1.424	.1613
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.46875	1.473	.1726
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.484375	1.522	.1843
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.5	1.571	.1962
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.515625	1.620	.2085
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.53125	1.669	.2217
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.546875	1.718	.2357
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.5625	1.767	.2505
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.578125	1.816	.2663
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.59375	1.865	.2829
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.609375	1.914	.2996
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.625	1.963	.3164
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.640625	2.012	.3333
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.65625	2.062	.3502
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.671875	2.111	.3675
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.6875	2.160	.3852
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.703125	2.209	.4033
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.71875	2.258	.4217
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.734375	2.307	.4404
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.75	2.356	.4594
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.765625	2.405	.4784
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.78125	2.454	.4974
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.796875	2.503	.5167
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.8125	2.552	.5363
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.828125	2.601	.5566
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.84375	2.650	.5771
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.859375	2.700	.5980
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.875	2.749	.6193
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.890625	2.798	.6413
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.90625	2.847	.6638
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.921875	2.896	.6863
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.9375	2.945	.7093
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.953125	2.994	.7325
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.96875	3.043	.7561
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	.984375	3.092	.7801
$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1}$	1.0	3.142	.8044

